Volume 30 JULY, 1956 Number 4

PALEONTOLOGY

JOURNAL OF PALEONTOLOGY

UNIVERSITY OF MICHIGAN
SEP 17 1956
MUSEUMS LIBRARY

A publication of The Society of Economic Paleontologists and Mineralogists *and* The Paleontological Society *with the generous support and cooperation of* The American Association of Petroleum Geologists *and* The Geological Society of America

CONTENTS

Permian fusulines from Nevada ..... *Raymond L. Knight* 773

Fusulinids of the Desmoinesian—Missourian contact ..... *M. L. Thompson, G. J. Verville,* and *D. H. Lokke* 793

Goniatites from the Middle Devonian Columbus limestone of Ohio ..... *Walter C. Sweet* and *A. K. Miller* 811

Triassic conodonts from Nevada ..... *Klaus J. Müller* 818

Upper Pennsylvanian arenaceous Foraminifera from Kansas ..... *H. A. Ireland* 831

Notes concerning a Senonian valvulinerian ..... *R. W. Harris* and *C. L. McNulty, Jr.* 865

A new occurrence of Mississippian Ostracoda in Michigan ..... *Marilyn Joyce Crane* and *William A. Kelly* 869

Khmeria and *Trachypsammia* from the Permian of Sosio, Sicily ..... *Eugenia Montanaro Gallitelli* 876

New Foraminifera from the Cenomanian of Sinai, Egypt ..... *S. Omara* 883

Tertiary Foraminifera of coastal Ecuador: Part II, additional notes on the Eocene species ..... *J. Hofker* 891

PALEONTOLOGICAL NOTES 959

REVIEWS 981

SOCIETY RECORDS AND ACTIVITIES

Reports and Minutes 991

Program and Abstracts 995

Annual Business Meeting 1012

Program and Abstracts of Pacific Section, S.E.P.M. 1026

NOTICE 1028

EDITORS

For The Paleontological Society: WILLIAM R. EVITT, The Carter Oil Co., P. O. Box 801, Tulsa, Oklahoma.

For The Society of Economic Paleontologists and Mineralogists: W. M. FURNISH, Department of Geology, State University of Iowa, Iowa City, Iowa.

The JOURNAL OF PALEONTOLOGY is published bimonthly. The issues for January, May, and September are sponsored by The Paleontological Society in cooperation with The Geological Society of America; those for March, July, and November are sponsored by The Society of Economic Paleontologists and Mineralogists in cooperation with The American Association of Petroleum Geologists.

The subscription price for the JOURNAL is $15.00 per year prepaid to addresses in the United States. Postage is charged extra for all other countries in the Postal Union, 40 cents on annual subscriptions (total $15.40). Single numbers $3.00 each to nonmembers, $1.75 to members.

Communications about the JOURNAL, advertising, subscriptions, rates, change of address, and nonreceipt of preceding numbers, should be addressed to The Society of Economic Paleontologists and Mineralogists, P. O. Box 979, Tulsa 1, Oklahoma. Claims for nonreceipt of preceding numbers must be submitted within three months of the date of publication in order to be filled gratis. Communications about membership and requests for blanks for nomination of new members should be directed to the secretary of the respective society.

Communications in regard to manuscripts or purely editorial matters should be sent to the editors at addresses above.

Authors should consult a recent issue of the JOURNAL for appropriate style and form before preparing their manuscripts. A brief, informative abstract should accompany every article except nomenclatural notes only one or two paragraphs long in which the title is sufficient to serve as an abstract of the contents. All new taxonomic names proposed in a paper should appear in the abstract.

Contributors are requested to instruct their photographers to illuminate fossils from the upper left side, the conventional manner. Plates normally should be arranged for publication at the maximum size of 5¾×8½ inches, exclusive of margins and heading. Printed numerals of standard size and form may be obtained free from the editors. When requesting them state number of plates and dimensions of each plate. Text-figures should be designed for reproduction at either single column (2⅜ inches) or full page (5¾ inches) width, maximum height 7½ inches. Typewritten copy is not acceptable for text-figures.

OFFICERS OF THE SOCIETIES

THE SOCIETY OF ECONOMIC PALEONTOLOGISTS AND MINERALOGISTS

For the year ending March 1957

President
ROBERT R. SHROCK, Cambridge, Mass.

Vice-President
R. V. HOLLINGSWORTH, Midland, Texas

First Past President
F. J. PETTIJOHN, Baltimore, Md.

Secretary-Treasurer
S. P. ELLISON, JR., Austin, Texas

Editors
W. M. FURNISH, Iowa City, Iowa
for paleontology
JACK L. HOUGH, Urbana, Ill.
for mineralogy

THE PALEONTOLOGICAL SOCIETY

For the year ending November 1956

President
HENRYK B. STENZEL, Houston, Texas

Vice-President
GLENN L. JEPSEN, Princeton, N. J.

Secretary
HARRY B. WHITTINGTON, Cambridge, Mass.

Treasurer
CLAUDE C. ALBRITTON, Dallas, Texas

Editor
WILLIAM R. EVITT, Rochester, N. Y.

Past Presidents
A. SCOTT WARTHIN, JR., Poughkeepsie, N. Y.
HARRY S. LADD, Washington, D. C.
W. STORRS COLE, Ithaca, N. Y.

Entered as second-class matter at the Post Office at Tulsa 1, Oklahoma, under the Act of March 1879. Acceptance for mailing at special rate of postage provided for in paragraph 4, section 538, P. L. and R, authorized April 3, 1935.

Additional entry as second-class matter at the Post Office at Menasha, Wisconsin.

Printed in U. S. A.

GEORGE BANTA COMPANY, INC., MENASHA, WISCONSIN

JOURNAL OF PALEONTOLOGY

A publication of THE SOCIETY OF ECONOMIC PALEONTOLOGISTS AND MINERALOGISTS *and* THE PALEONTOLOGICAL SOCIETY *with the generous support and cooperation of* THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS *and* THE GEOLOGICAL SOCIETY OF AMERICA

VOLUME 30 | JULY, 1956 | NUMBER 4

PERMIAN FUSULINES FROM NEVADA

RAYMOND L. KNIGHT
Shell Oil Company, Durango, Colorado

ABSTRACT—The age of a hitherto undescribed interval of the Arcturus formation (Permian) in White Pine County, Nevada has been determined to be equivalent to a zone bracketing the upper Leonard and lower Word formations of Texas. This conclusion is based upon a fusulinid fauna composed of almost equal proportions of the genera *Parafusulina* and *Schwagerina*, although one member of the genus *Pseudofusulina* is present.

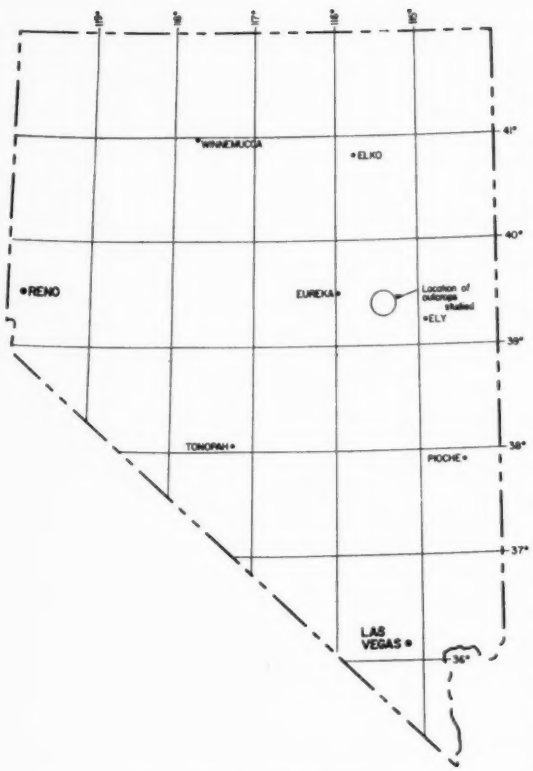
Eleven new species and one new variety are named; one of these is from a large collection of random samples not taken in conjunction with the measured sections studied. Vertical ranges have been plotted as they occur within two stratigraphic sections.

INTRODUCTION

DURING Permian time both marine and continental sediments were deposited over much of the western half of the United States. Outcrops are present locally in eastern Nevada and western Utah where field units have been recognized without knowledge of their exact position within the Permian. In White Pine County, Nevada, where the present work was done, one of these units has been assigned to the Middle Permian by studying the ranges of the contained fusulinid fauna.

The two intervals measured are in close proximity to Moorman Ranch, a local landmark on the south side of U. S. Highway No. 50 some 31 miles west of Ely, Nevada. (Text-fig. 1.) Section 1 has its initial point 2 miles west of the Ranch just 60 feet east of the intersection of U.S. Highway 50 and the dirt road north to Pine Valley. Section 2 was measured upward from a point approximately 300 feet above road level in the fault valley northwest of Moorman Ranch. This valley, a small, but prominent feature, intersects the highway 0.8 mile west of Moorman Ranch. (Text-fig. 2.) Rocks exposed at this location consist of a monotonous alternating sequence of buff, fine- to medium-grained limestones and white to buff, calcareous, fine- to medium-grained sandstones; every gradation between these types is present along the strike or vertically within some of the units. Secondary chert occurs in both the limestones and in the more calcareous sandstones, making up 25 percent of a bed in some cases. Slightly over 900 feet of Permian rocks were measured at the thickest section studied (Section No. 2.). Field work suggests that this unit is equivalent to at least part of the Arcturus formation as defined by Spencer (1917). Due to erosion at the top and structural complications at the base, it is impossible to obtain the true thickness of the formation at Moorman Ranch. In spite of these difficulties the section at this locality offered the thickest Permian sequence known at the time the study was undertaken.

Faunal ranges and descriptions are based on the study of approximately 300 thin sections and 400 polished surfaces. It is estimated that at least 7000 individual fusulinid



TEXT-FIG. 1—Index map.

specimens were seen in this way. An additional 100 thin sections, made from random collections, were compared with the Moorman Ranch material—*Parafusulina sublinearis*, n. sp.; *Triticites secalicus oryziformis* Newell, and *Fusulinella devexa* Thompson came from these samples. The last species is of Pennsylvanian age.

Study of fusulinds offers the only ready approach to dating these rocks because megafossils are quite rare in the sections. W. H. Easton (personal communication) has identified *Waagenophyllum*, n. sp., *Dictyoclostus ivesi*, and *Omphalotrochus* sp. from various stratigraphic horizons in the measured sections. Although these indicate a Permain age their exact ranges in Nevada nave not yet been established.

ACKNOWLEDGMENTS

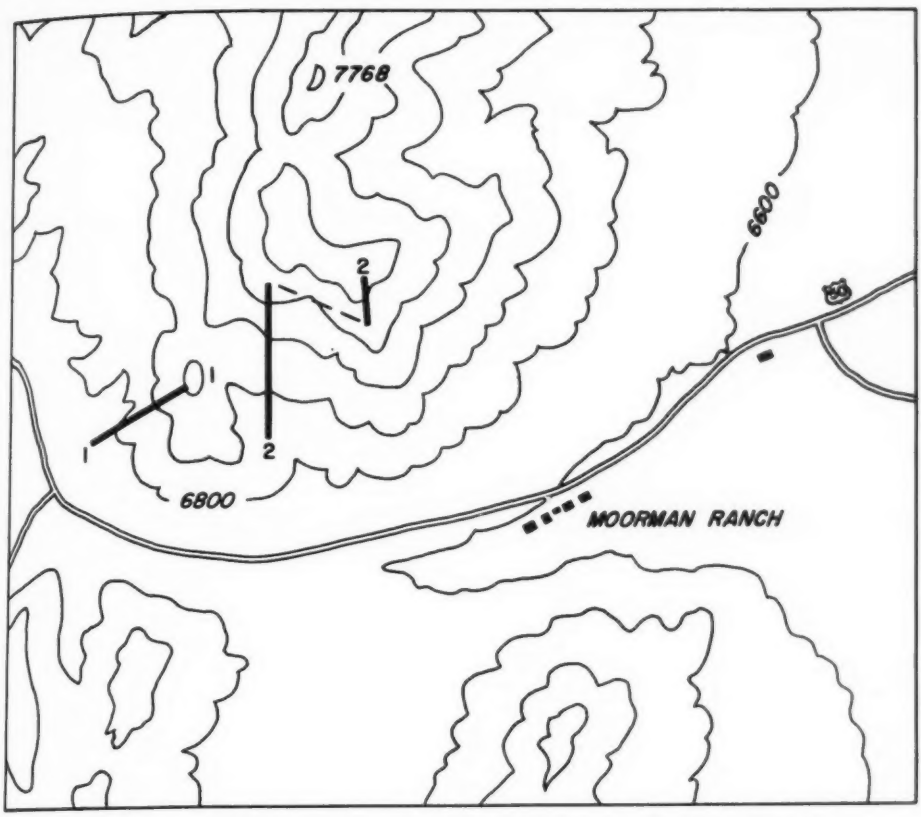
Dr. W. H. Easton suggested the problem and actively helped in the field as well as during the preparation of the report. Dr. O. L. Bandy and Dr. Thomas Clements are also to be thanked for their continued interest. Field accommodations and financial aid were provided by the Union Oil Company of California through the courtesy of Dr. John C. Hazzard. Mr. William Fortin of the Alan Hancock Foundation at the University of Southern California gave the writer assistance in the preparation of illustrations. The study represents part of a thesis submitted for the degree of Master of Arts at the University of Southern California. Published by permission of the Shell Oil Company.

FAUNAL ASPECTS

Cuniculi have been observed from suitably oriented specimens in nearly all of the samples collected, indicating that the *Parafusulina* stage of evolutionary development had been reached by the time Moorman Ranch Permian rocks were deposited. On this basis, ten species are referred to the genus *Parafusulina;* they are associated with eight species of *Schwagerina* and one member of the genus *Pseudofusulina.*

Parafusulina apiculata, n. sp., *P. bösei* Dunbar & Skinner, and *Schwagerina modica* Thompson & Hazzard are confined almost exclusively to the upper one-third of the two measured sections. *Parafusulina* sp. A. is seemingly restricted to the bottom one-third, and *Schwagerina moormanensis*, n. sp., is found in the middle one-third of both sections. Other than these examples, there is a tendency for long individual ranges; *Schwagerina guembeli* Dunbar & Skinner, for example, ranges throughout almost 800 feet of section 2 and over 600 feet of section 1. Text-figure 3 illustrates the ranges of the individual species in the columnar sections.

The fauna of these rocks may be placed in the "Zone of *Parafusulina*" as defined by Thompson (1948), but its exact position in respect to the Texas Permain is not so easily ascertained. Only one species and its variety, *Schwagerina guembeli* and *S. guembeli pseudoregularis*, characteristic of the lower 500 feet of the Leonard formation have been identified from this material; no other representative of the lower faunal zone (Dunbar & Skinner, 1937, p. 586) has been observed. Both *Parafusulina bösei* and *P. splendens*, found in the lower Word formation, are present throughout almost the en-



TEXT-FIG. 2—Location of measured section in relation to Moorman Ranch, White Pine County Nevada.

tire thickness of both intervals along with *S. guembeli*. *Parafusulina visseri*, *P. shaksgamensis*, and *P. visseri lata*, are known also from the upper Artinskian of Kashmir, a stratigraphic position equivalent to the middle of the Leonard formation in the Glass Mountains of Texas (Dunbar, 1940). These data plus the equal division of the fauna into species of *Schwagerina* and *Parafusulina* lead the writer to believe that these sediments at Moorman Ranch are equivalent to a zone that would bracket the upper Leonard and lower Word formations of the Glass Mountains of Texas.

Fauna of the random samples.—One of the random samples (WHE 217) presents an anomalous association of the two genera, *Triticites* and *Parafusulina*. The only other known occurrence of this assemblage seems to be that given by Thompson, Wheeler & Hazzard (1946); they record a very primitive *Parafusulina* together with what appears to be a *Triticites*. The same situation prevails in sample WHE 217 which contains *P. sublinearis* n. sp. and *Triticites secalicus oryziformis* Newell. This material is Lower Permian in age and is believed to represent a zone at the very top of the Wolfcampian similar to the subzone of *Schwagerina linearis* found in Texas.

All specimens are deposited in the paleontological collection of the University of Southern California.

SYSTEMATIC PALEONTOLOGY

Genus FUSULINELLA Moller, 1877

FUSULINELLA DEVEXA Thompson

Pl. 83, fig. 1–3

Fusulinella devexa THOMPSON, 1948, Univ. Kansas Pub., Art. No. 1, p. 94; pl. 32, fig. 6,10; pl. 35, fig. 1–15; pl. 36, fig. 7–10,12–17.

This species represents the only member

TEXT-FIG. *3*—Columnar section with faunal ranges.

of the subfamily Fusulininae found in the samples examined. Its shell is rather small, inflated fusiform, having slightly concave lateral slopes and a straight axis of coiling. Large individuals of 6 volutions are from 2.1 to 3.6 mm. long and over 1.1 mm. in width. The form ratio in the first volution is approximately 2.0 and there is very little change in the succeeding volutions. A greater equatorial inflation is noticed in the inner whorls than the outer ones.

The proloculus is small and spherical with outside diameters varying from 75 to 100 microns. The test expands uniformly with the chamber height remaining almost constant from the equator to the poles.

The spirotheca is typical of the genus, showing a distinct tectum and diaphanotheca with inner and outer tectoria. The spirotheca is approximately 25 microns thick in the outer volutions.

Only one equatorial section was obtained and the septal count per whorl is given in the tabulation of data. Septal folding is weak and restricted to the extreme poleward ends, thus the lateral slopes are plain almost their entire length.

Measurements of *Fusulinella devexa* Thompson, in mm.

	Half length		Radius vector		Form ratio		Septal count	Tunnel angle	
1.	0.14	0.20	0.09	0.11	1.55	1.8	8	12	13
2.	0.22	0.35	0.12	0.17	1.80	2.0	15	13	17
3.	0.40	0.57	0.19	0.29	2.10	2.0	16	19	21
4.	0.67	0.95	0.27	0.42	2.5	2.2	20	22	29
5.	0.75	1.32	0.37	0.60	2.0	2.2	23	31	37
6.	1.07	1.80	0.55	—	1.9	—		36	

The tunnel angle is small in the first two volutions, but gradually becomes wider in each following whorl till it reaches a value of from 31 to 37 degrees in the fifth or sixth volution. Asymmetrical chomata border the tunnel and in places are as high as the chamber. The low slope side of these chomata extends almost to the poles in the outer volutions.

Remarks.—The specimens measured have a slightly larger tunnel angle than the average for *Fusulinella devexa* Thompson and a slightly lower form ratio, although they possess the same constancy of form ratio (near 2.0) through the middle portion of the shell.

These forms have been reported by Thompson (1948, p. 94) from the Chuchillo Negro formation (lower Middle Penn.), Mud Springs Mountains, southern New Mexico.

Occurrence.—From a limestone bluff at the crest of the range 200 yards north of the prominent rounded peak in center of the N/2, SE/4, Section 27, T. 17 N., R. 61 E., White Pine Co., Nevada (Ely limestone). Also from east-dipping limestone exposed in the road through Silver Spring Wash, approximately 1 mile northeast of Silver Spring and $\frac{1}{4}$ to $\frac{1}{2}$ mile east of the canyon mouth, Sec. 13, T.8N., R.62E., Lincoln Co., Nevada. Sample numbers WHE 115 and 174.

Genus TRITICITES Girty, 1904
TRITICITES SECALICUS ORYZIFORMIS Newell, 1934
Pl. 83, fig. 4–6

Triticites secalicus oryziformis NEWELL, 1934, Jour. Paleont., vol. 8, p. 424; pl. 52, fig. 3a–d; pl. 53, fig. 3.

This medium-sized species, of from 6 to 7 volutions, varies in general outline from subcylindrical to non-inflated elongate fusiform. It has an axis of coiling that is straight to very slightly curved with poles that are widely rounded, at least in the outer volutions. The length ranges from 6.4 to 7.0 mm. in the seventh volution. Corresponding diameters are 2.1 and 2.4 mm. The form ratio varies from near unity in the first volution to a value close to 3.0 in the last two whorls. The second to the fourth volutions appear fusiform, while the later whorls become more and more cylindrical.

The outside diameters of the two proloculi measured varied from 225 to 275 microns. Both of these are relatively thick-walled and spherical in shape. The tests expand uniformly and the heights of the chambers increase somewhat toward the poles although the lateral slopes show no tendency toward becoming concave.

The spirotheca is definitely of the schwa-

gerine type with a prominent keriotheca. Alveoli are abundant and appear to be quite even and thin. The wall is approximately 70 microns thick in the outer whorls.

Only one equatorial section of 6½ volutions was obtained; the number of septa per whorl are shown below. Septal folding is very low and almost lacking in the equatorial area, becoming more intense toward the poles. This almost complete restriction of septal folding to the pole areas may indicate a rather primitive member of the genus.

The tunnel is well developed and is bounded by heavy chomata that overhang the tunnel in the fourth and fifth volutions. They appear to be reduced greatly in the last whorls.

Genus SCHWAGERINA Moller, 1877
SCHWAGERINA GUEMBELI
Dunbar & Skinner
Pl. 83, fig. 7–10

Schwagerina guembeli DUNBAR & SKINNER, 1937, Univ. Texas Bull., Bur. Econ. Geol., no. 3701, vol. 3, pt. 2, p. 639; pl. 61, fig. 1–13.

The test of *S. guembeli* is medium-sized, has a spindle-shaped axial profile, even lateral slopes, and a straight axis of coiling. Individuals of 5 to 6 volutions are 5.5 to 6 mm. in length and 2.5 to 3 mm. wide. The form ratio remains almost uniformly at a value of 2.0 throughout growth. The typical flattened ellipse profile also remains constant during shell development.

Measurements of *Triticites secalicus oryziformis* Newell, in mm.

	Half length			Radius vector			Form ratio			Septal count	Tunnel angle	
1.	0.20	0.30	0.15	0.15	0.17	0.12	1.3	1.7	1.2	9	18	20
2.	0.37	0.52	0.32	0.24	0.32	0.20	1.6	1.6	1.6	14	22	24
3.	0.67	0.87	0.62	0.35	0.37	0.27	1.9	2.3	2.3	13	32	34
4.	1.07	1.30	1.10	0.50	0.52	0.42	2.1	2.5	2.6	13	33	38
5.	1.50	1.90	1.55	0.70	0.70	0.60	2.1	2.7	2.6	17	34	56
6.	2.15	2.77	2.25	0.97	0.92	0.80	2.2	3.0	2.8	19		52
7.		3.50	3.20		1.20	1.05		2.9	3.0			

Remarks.—This species is found in association with *Parafusulina sublinearis*, n. sp. in sample WHE-217. The type is from the Westphalia limestone (Middle Pennsylvanian) of Kansas. The variety differs from *T. secalicus* (Say) in having a much larger proloculus and is slightly shorter in length.

Occurrence.—Same as *Parafusulina sublinearis.*

The spherical proloculus is 35 to 40 microns thick and ranges from 250 to 350 microns in outside diameter. An average for four proloculi gives a value of 287 microns. The shell is tightly coiled for the first 1½ to 2 volutions then it expands uniformly. Chamber heights are uniform from the equator poleward.

A thin tectum and a well developed,

EXPLANATION OF PLATE 83

All figures ×9

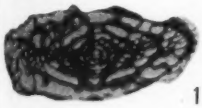
FIG. *1–3*—*Fusulinella devexa* Thompson. *1*, Axial section; hypotype; U.S.C. 3157. *2*, Equatorial section; hypotype; U.S.C. 3157. *3*, Axial section; hypotype; U. S. C. 3156.

4–6—*Triticites secalicus oryziformis* Newell. *4*, Equatorial section; hypotype; U.S.C. 3107. *5*, Axial section; hypotype; U.S.C. 3108. *6*, Axial section; hypotype; U.S.C. 3107.

7–10—*Schwagerina guembeli* Dunbar & Skinner. *7*, Axial section; hypotype; U.S.C. 3109. *8*, Axial section; hypotype; U.S.C. 3110. *9*, Equatorial section; hypotype; U.S.C. 3111. *10*, Tangential slice showing elongated chamberlets; hypotype; U.S.C. 3109.

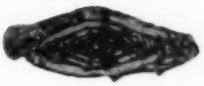
11,12—*Schwagerina medullaris* Knight, n. sp. *11*, Equatorial section; paratype; U.S.C. 3112. *12*, Axial section; holotype; U.S.C. 3113.

13,14—*Schwagerina guembeli pseudoregularis* Dunbar & Skinner. *13*, Equatorial section; hypotype; U.S.C. 3114. *14*, Axial section; hypotype; U.S.C. 3115.

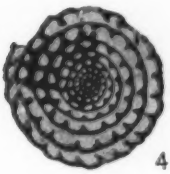


1

2

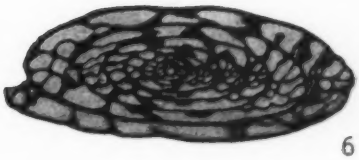


3

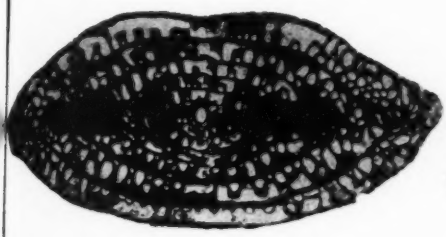


4

5



6



7

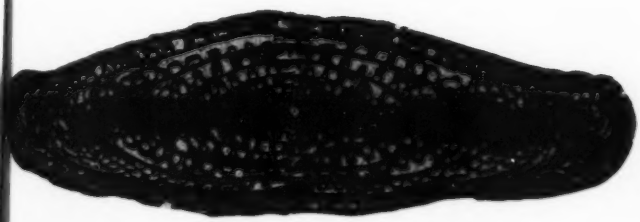
8

9

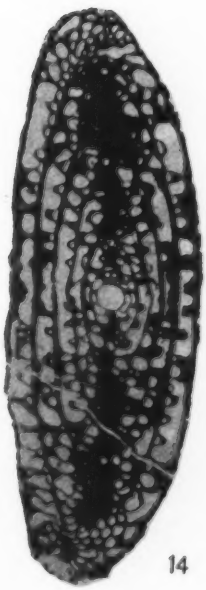
10

11

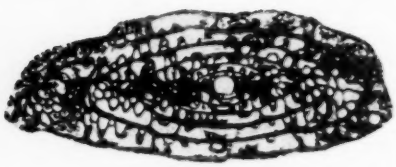
13



12

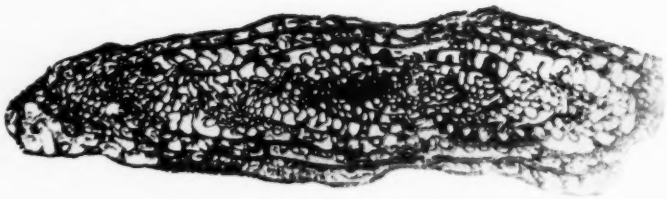


14

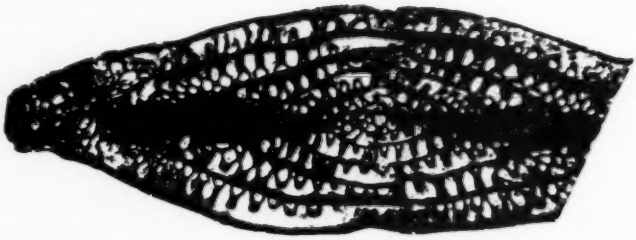


1

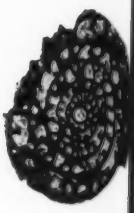
2

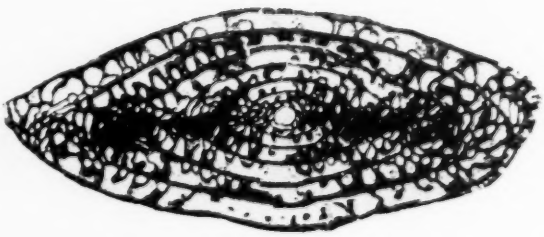


4

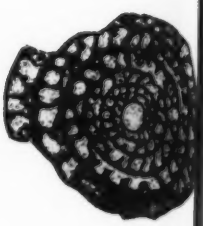


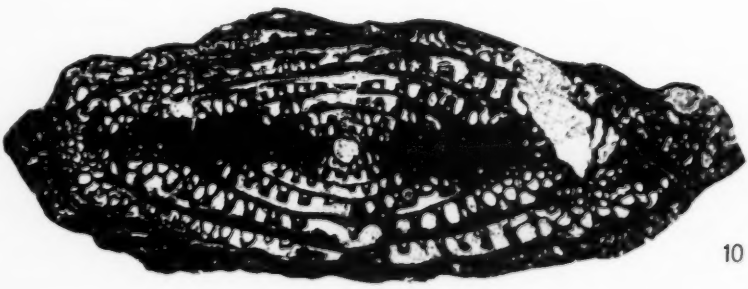
6



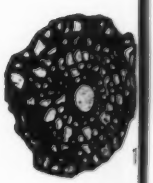


8





10



coarsely alveolar keriotheca are shown by the spirotheca which is initially 20 to 35 microns thick and reaches a thickness of 80 to 115 microns in the outer whorls.

Ten to 12 septa are present in the first whorl and this number increases to 30 or 35 in the 6th or 7th volution.

Septal folding extends the entire length of the shell and in tangential sections there is a definite elongation of the chamberlets. However, the points of contact do not become excavated as in the genus *Parafusulina*. In axial sections the septal loops are predominantly truncated triangles or irregular rectangles. A slight development of phrenothecae occurs in the outer whorls.

The tunnel angle is obscure in axial thin-sections and no chomata are present. Axial filling in the form of two dark spots is concentrated in the poles of the first 4 volutions.

bottom to very near the top of both measured intervals.

SCHWAGERINA GUEMBELI PSEUDOREGULARIS Dunbar & Skinner
Pl. 83, fig. 13,14

Schwagerina guembeli pseudoregularis DUNBAR & SKINNER, 1937, Univ. Texas Bull., Bur. Econ. Geol., no. 3701, vol. 3, pt. 2, p. 640; pl. 61, fig. 14–24.

Members of this variety are medium-sized, cylindrical, have evenly convex lateral slopes, straight axis of coiling, and bluntly rounded poles. Individuals of 6 volutions are 5.2 to 7.5 mm. in length and 2.0 to 2.6 mm.wide. The form ratio is 2.0 in the second volution and reaches a value of 2.6 to 2.8 in the 6th whorl. Little change is observed in the axial outline during growth except a slight increase in pole rounding.

Measurements of *Schwagerina guembeli* Dunbar & Skinner, in mm.

	Half length		Radius vector		Form ratio		Septal count	
1.	0.37	0.45	0.35	0.27	1.1	1.6	12	10
2.	0.82	0.85	0.50	0.40	1.7	2.1	21	18
3.	1.20	1.27	0.67	0.60	1.8	2.1	20	18
4.	1.87	1.60	0.92	0.80	2.0	2.0	24	24
5.	2.50	2.12	1.22	0.95	2.0	2.2	29	26
6.	3.03		1.45		2.1		32?	27

Remarks.—The types of this species are from 450 feet above the base of the Leonard formation, Glass Mountains, Texas. An examination of both fig. 7 and 8, Pl. 83, of this paper and the original series of cotypes shows a rather wide variation in form. It is thought that *S. guembeli* should be restricted to the spindle-shaped forms and the elliptical forms with large proloculi set up as a variety of this species. This is not done, due to the lack of adequate sagittal sections.

Occurrence.—This form is found from the

Three spherical proloculi vary from 250 to 425 microns in outside diameter and have a wall thickness from 25 to 40 microns. The shell expands uniformly and is loosely coiled. Chamber heights are remarkably uniform from the equator poleward.

The spirotheca consists of a distinct tectum and a well developed keriotheca. Its initial thickness is approximately 45 microns and the maximum recorded in the 6th volution is 90.

Septa in the first 4 volutions remain close

EXPLANATION OF PLATE 84

All figures ×9

FIG. *1–3*—*Schwagerina modica* Thompson & Hazzard. *1*, Axial section; hypotype; U.S.C. 3116. *2*, Equatorial section; hypotype; U.S.C. 3117. *3*, Equatorial section; hypotype; U.S.C. 3118.

4,5—*Schwagerina moormanensis* Knight, n. sp. *4*, Axial section; holotype; U.S.C. 3119. *5*, Equatorial section; paratype; U.S.C. 3120.

6,7—*Schwagerina mucronata* Knight, n. sp. *6*, Axial section; holotype; U.S.C. 3121. *7*, Equatorial section; paratype; U.S.C. 3122.

8,9—*Schwagerina subinflata* Knight, n. sp. *8*, Axial section; holotype; U.S.C. 3123. *9*, Equatorial section; paratypes; U.S.C. 3124.

10,11—*Schwagerina retusa* Knight, n. sp. *10*, Axial section; holotype; U.S.C. 3125. *11*, Equatorial section; paratype; U.S.C. 3126.

to 20 per whorl. Folding extends the length of the shell and is seen in axial section as low, widely spaced loops. In tangential sections there is a tendency toward elongation without excavation.

The tunnel is narrow and irregular. Chomata are present in the first 2 volutions, after which they disappear. Two elongated spots of axial filling are concentrated in the poles of the 2nd to 5th volutions.

crons. The shell is tightly coiled and the lateral slopes are nearly parallel from the equator to the poles.

The spirotheca consists of a distinct, but thin, tectum and a moderately coarse keriotheca. Initially it is about 30 microns in thickness and increases irregularly until it reaches 75 to slightly over 100 microns in the last whorl.

A septal count on the only oriented equa-

Measurements of *Schwagerina guembelina pseudoregularis* Dunbar & Skinner, in mm.

	Half length		Radius vector		Form ratio		Septal count
1.	0.47	0.25	0.30	0.17	1.6	1.4	11
2.	0.87	0.55	0.42	0.27	2.0	2.0	20
3.	1.50	0.87	0.55	0.37	2.7	2.3	23
4.	2.25	1.50	0.77	0.55	2.9	2.7	21?
5.	3.00	2.12	1.02	0.75	2.9	2.8	
6.	3.75	2.60	1.32	1.00	2.8	2.6	

Remarks.—The types of this variety are from 450 feet above the Leonard formation, Glass Mountains, Texas.

Occurrence.—Possibly ranges throughout both measured sections. Not common.

SCHWAGERINA MEDULLARIS Knight, n. sp.
Pl. 83, fig. 11,12

These large tests are slightly inflated-fusiform, have evenly convex lateral slopes, rounded poles, and a straight axis of coiling. Individuals of 7 to 8 volutions are from 8 to 9 mm. long and about 2.5 mm. wide. Their form ratio, near 2.0 for the first 5 volutions, increases gradually to approximately 3.0 in the 7th or 8th whorl. There is little change in outline during growth.

The outside diameter of the proloculus ranges from 200 to 250 microns. All the shells appeared distorted in and around the central area with the exception of one very good equatorial section which measured 225 mi-

torial section available gave 16, 21, 25, 29, and 28 septa in the 2nd to the 6th volution. Folding of septa extends the entire length of the shell and becomes vesicular in the outer 2 or 3 volutions. Rounded to slightly elongated chamberlets are seen in tangential slices although the septal loops in axial view are roughly rectangular in the middle part of the test. A slight development of phrenothecae occurs in the outer volutions.

The tunnel is obscure, although rudimentary chomata border it in the first 4 volutions. Secondary filling is concentrated in a dark band that follows the axis of all but the last 2 volutions.

Remarks.—*Schwagerina medullaris* does not closely resemble any other species of *Schwagerina*. Heavy elongated axial filling, tight coiling, and bluntly rounded poles easily distinguish it from *Schwagerina mucronata* in spite of similarities in axial filling patterns.

Measurements of *Schwagerina medullaris*, n. sp., in mm.

	Half length				Radius vector				Form ratio				Septal count
1.	0.25	0.30	0.32	0.17	0.15	0.22	0.30	0.15	1.7	1.3	1.1	1.2	—
2.	0.52	0.55	0.67	0.40	0.25	0.27	0.42	0.25	2.1	2.0	1.6	1.6	16
3.	0.82	1.25	1.07	0.60	0.35	0.50	0.65	0.37	2.3	2.5	1.7	1.6	21
4.	1.10	1.50	1.55	0.97	0.50	0.67	0.90	0.50	2.2	2.2	1.7	2.0	25
5.	1.50	2.22	2.62	1.32	0.67	0.90	1.20	0.72	2.2	2.5	2.2	1.8	29
6.	2.25	3.00	3.62	2.02	0.87	1.02	1.50?	0.95	2.6	2.9	2.9?	2.2	28
7.	3.12	4.12		3.18	1.05	1.27		1.20	3.0	3.2		2.6	
8.	3.62			4.64	1.25			1.43	2.9			3.2	

Occurrence.—Ranges from near the bottom of the two sections to within some 50–100 feet of the top.

SCHWAGERINA MODICA
Thompson & Hazzard
Pl. 84, fig. 1–3

Schwagerina modica THOMPSON, WHEELER, & HAZZARD, 1946, Geol. Soc. Amer., Mem. 17, p. 44; pl. 11, fig. 1–7.

Individuals belonging to this species are medium-sized, inflated-fusiform, show only a very slight tendency toward concavity of the lateral slopes, and have a straight axis of coiling. Tests of 5 or 6 volutions are from 5 to 6 mm. long and about 2.2 mm. in width. Form ratio increases gradually from 2.0 to near 3 in the outer volutions. There is a tendency toward rounding of the poles after the 3rd volution.

The outside diameter of the thin-walled, subspherical proloculus ranges from 200 to 300 microns. Shell expansion is uniform and the height of the chambers remains nearly constant from the equator to the poles.

The spirotheca has a distinct tectum and a keriotheca that contains relatively coarse alveoli. Initially it is near 30 microns thick and is only 60 to 75 microns in thickness at the 6th volution.

About 10 septa are present in the first whorl and the number reaches 29 in the 7th volution. Folding is low, and not intense, although it extends the entire length of the shell. In tangential sections, round cell-like chambers are formed, but the tips are not excavated.

The tunnel is of moderate width, but is very irregular. Chomata are not present even though axial filling is located in the poles of the first 4 volutions.

Remarks.—*S. modica* was described from the Bird Spring formation (Lower Permian) of southern California. The writer's specimens are identical with the types, with the exception that the outer whorls have fewer septa per whorl. The slight variation in form ratio is explained by the bending in of the last few whorls.

Occurrence.—Abundant in the top quarter of both measured sections.

Measurements of *Schwagerina moormanensis*, n. sp., in mm.

	Half length			Radius vector			Form ratio			Septal count		
1.	0.55	0.47	0.40	0.22	0.25	0.25	2.4	1.9	1.6	—	—	16
2.	0.87	0.75	0.80	0.35	0.35	0.45	2.5	2.1	1.8	20	15	17
3.	1.45	1.25	1.77	0.45	0.50	0.62	3.2	2.5	2.8	19	24	19
4.	2.40	2.25	2.90	0.57	0.65	0.82	4.2	3.4	3.5	18	20	21
5.	4.00	3.00	4.43	0.80	0.75	1.02	5.0	4.0	4.3	21	23?	
6.	5.00	3.62	6.06	0.95	0.90	1.25	5.3	4.0	4.8	—	24	
7.	5.50	4.75		1.25	1.12		4.4	4.2		24		

SCHWAGERINA MOORMANENSIS
Knight, n. sp.
Pl. 84, fig. 4–5

Shells of this species are large, elongate-fusiform, have slightly concave lateral slopes, at least in the outer volutions, and a curved axis of coiling. Individuals of 6 to 7 whorls are from 9.8 to 12.0 mm. in length and 2.5 to 2.24 mm. wide. The initial form ratio is near 2.0, although it changes during growth to a value between 4.0 and 5.0 in the mature stage. The first 4 to 5 volutions show pointed poles which progressively become more rounded with growth.

The outside diameter of the proloculus varies from 200 to 300 microns and is subspherical in outline. Its wall is between 40 and 50 microns thick. The test is tightly

Measurements of *Schwagerina modica* Thompson & Hazzard, in mm.

	Half length			Radius vector			Form ratio			Septal count		
1.	0.25	0.40	0.25	0.22	0.20	0.17	1.1	2.0	1.4	10	10	9?
2.	0.45	0.75	0.45	0.32	0.32	0.27	1.4	2.3	1.6	16	16	17
3.	0.82	1.20	0.77	0.45	0.45	0.40	1.8	2.7	1.9	19	22	18
4.	1.32	1.62	1.20	0.67	0.62	0.55	2.0	2.6	2.2	22	23	20
5.	2.15	2.50	1.85	0.85	0.80	0.77	2.5	3.1	2.4	27		27
6.	3.17		2.92	1.12	1.02	1.17	2.8		2.5			27

coiled in the first 3 or 4 volutions, after which it expands uniformly. As the shell matures the septa become longer in relation to the height of the enclosing chamber and in axial views the chamber height increases slowly from the equator to the poles. This tendency has been accentuated by downfolding at the equator.

The spirotheca shows a distinct, but finely alveolar keriotheca. It is thin, starting around 25 microns and reaching about 90 in the last volution.

Septal counts change little throughout growth, never varying far from 20 per whorl. Folding reaches the length of the shell and septal arches extend nearly the height of the chambers. Extremely vesicular folding is often seen in the pole regions.

The tunnel is not well defined due to intense folding. Axial filling is present in the poles of the first 4 whorls.

Remarks.—*S. moormanensis*, n. sp., is closely similar to *S. franklinensis* Dunbar & Skinner. It differs in being slightly longer in the outer whorls; has a shorter diameter; a form ratio of about 5.0 at maturity, rather than 3.8, and lacks the large number of septa per whorl reported for S. *franklinensis*. The specific name refers to the Moorman Ranch, White Pine County, Nevada.

Occurrence.—Found in the middle of both measured sections.

SCHWAGERINA MUCRONATA
Knight, n. sp.
Pl. 84, fig. 6,7

These large fusiform shells have convex to slightly concave lateral slopes, a straight axis of coiling and sharply pointed poles. The specimen figured has a length of 9.8 mm. and a width of 2.9 mm. Its form ratio is near 2.0 in the 2nd and 3rd volution, 2.5 in the 4th and reaches 3.4 in the 6th. The shell retains its sharply pointed outline throughout growth.

The average outside diameter of 4 subspherical proloculi is 250 microns; the range of these being from 225 to 275. The shell is loosely coiled and expands uniformly. Chamber heights increase only slightly during growth.

The spirotheca, consisting of a thin tectum and a coarsely alveolar keriotheca, is near 35 microns in the 1st volution, 85 to 115 in the 4th. Its maximum thickness is 125 microns in the outer whorls.

Approximately 18 septa are present in the 2nd volution, 24 to 26 in the 4th and near 30 in the 5th and 6th. Septal folding extends the entire length of the shell and produces triangular axial loops in the first 4 volutions. Round chamberlets are seen in tangential slices. Phrenothecae are located in a random manner within the shell, although they are not abundant.

Measurements of *Schwagerina mucronata*, n. sp., in mm.

	Half length	Radius vector	Form ratio	Septal count		
1.	0.52	0.35	1.5	9	10	11
2.	0.97	0.50	2.0	17	19	17
3.	1.57	0.70	2.2	18	20	23
4.	2.37	0.95	2.5	24	24	26
5.	3.52	1.17	3.0	31	25	—
6.	4.87	1.45	3.4	29		

EXPLANATION OF PLATE 85

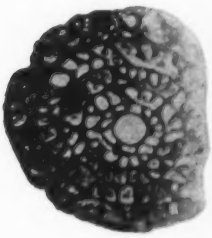
All figures ×9

FIG. *1*—*Schwagerina* sp. A.

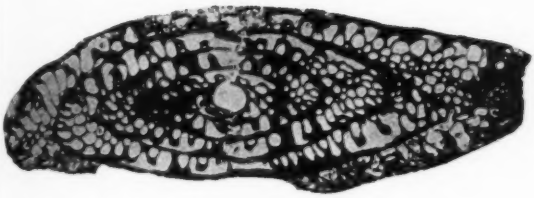
2–6—*Pseudofusulina lativentra* Knight, n. sp. *2*, Equatorial section; paratype; U.S.C. 3127. *3*, Axial section; holotype; U.S.C. 3128. *4*, Equatorial section; paratype; U.S.C. 3129. *5*, Axial section; paratype; U.S.C. 3130. *6*, Equatorial section; paratype; U.S.C. 3131.

7–10—*Parafusulina apiculata* Knight, n. sp. *7*, Axial section; paratype; U.S.C. 3132. *8*, Tangential slice showing cuniculi; hypotype; U.S.C. 3132. *9*, Axial section; Holotype; U.S.C. 3133. *10*, Equatorial section; paratype; U.S.C. 3134.

1

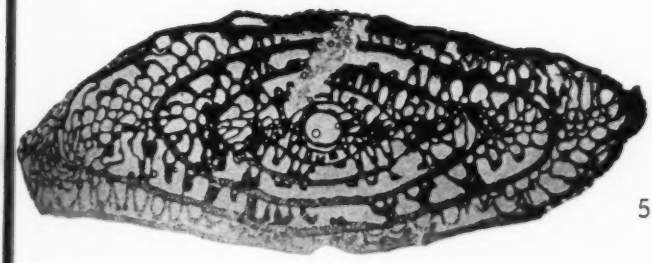


2

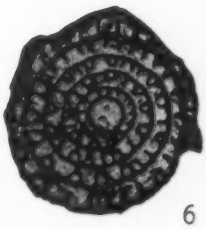


3

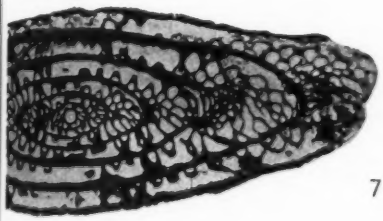
4



5

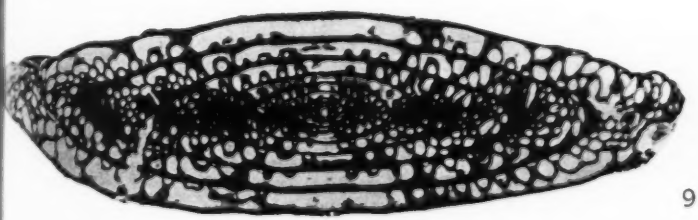


6



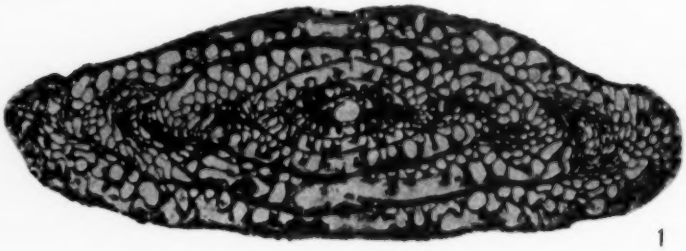
7

8

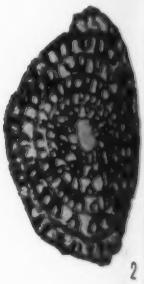


9

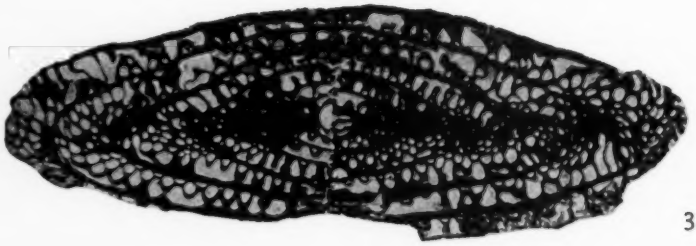
10



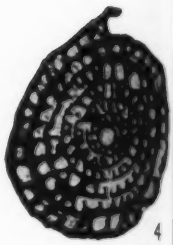
1



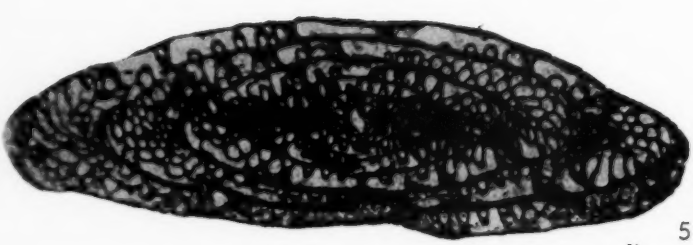
2



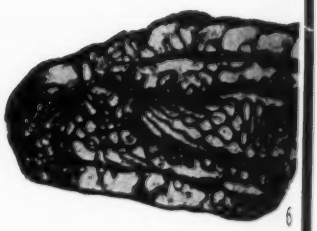
3



4

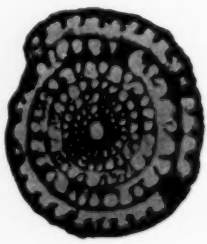


5

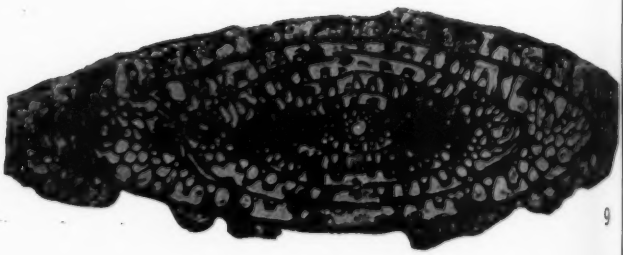


6

7



8



9

Chomata are not present and the tunnel is not well developed. Two elongated bands of secondary filling follow the axis in all but the last volution.

Remarks.—*Schwagerina mucronata*, n. sp., closely resembles *S. compacta* (White) in size and form ratio. *S. mucronata* shows a more concentrated and narrow axial filling and lacks the inflated equatorial region of *S. compacta*.

Occurrence.—There is a strong possibility that this species ranges through the bottom two-thirds of both sections.

SCHWAGERINA SUBINFLATA
Knight, n. sp.
Pl. 84, fig. 8,9

Tests of this species are moderately large, thickly fusiform, have convex lateral slopes, a slightly curved axis of coiling and pointed poles. Individuals of 6 to 7 volutions are about 7.5 mm. long and 2.75 to 2.9 mm. wide. The form ratio is near 2.0 until the 4th volution, where it rapidly increases to a value between 2.5 and 3.0. There is no striking change in outline throughout shell development.

The outside diameter of the subspherical to spherical proloculus varies from 325 to 400 microns, averaging 362 for 4 specimens. The shell expands uniformly and gives a rather loosely coiled appearance in axial section. There is a slight increase in chamber height poleward.

The spirotheca is 25 to 40 microns thick in the 1st volution, 85 to 100 in the 5th, and 80 to 90 in the 6th and 7th. It is composed of a tectum and a coarsely alveolar keriotheca.

Twenty to 25 septa are present in the 2nd whorl and 30 to 36 in the 5th. Folding extends the entire length of the shell, forming high, wide axial loops in the outer volutions. Elongated chamberlets are seen in tangential slices but the tips are not excavated.

Very small chomata border the moderately wide, but irregular tunnel in the first 3 volutions. Secondary filling is concentrated in the poles of all but the last 2 volutions. However, it is not strongly developed.

Remarks.—Closely resembles *S. crassitectoria* Dunbar & Skinner. It differs in being shorter; having a much larger proloculus and has much sharper poles than does *S. crassitectoria*. These specimens also lack the appearance of a central cylindrical portion shown by the cotypes.

Occurrence.—Near the top of both sections and at the bottom of Section 2.

Measurements of *Schwagerina subinflata*, n. sp., in mm.

	Half length		Radius vector		Form ratio		Septal count	
1.	0.27	0.47	0.22	0.30	1.2	1.6	13	13?
2.	0.52	0.77	0.35	0.45	1.5	1.7	20	25
3.	0.87	1.27	0.52	0.62	1.7	2.0	21	30
4.	1.40	1.90	0.72	0.87	1.9	2.2	25	28
5.	2.42	2.92	0.95	1.07	2.5	2.7	30	36
6.	2.90	3.79	1.17	1.37	2.5	2.8		
7.	3.77		1.45		2.6			

SCHWAGERINA RETUSA
Knight, n. sp.
Pl. 84, fig. 10,11

Tests of *S. retusa* are medium-sized, inflated-fusiform with bluntly rounded poles, evenly convex lateral slopes and a straight axis of coiling. Individuals of 6 volutions are 7.25 to 8.0 mm. long and 2.1 to 3.25 mm.

EXPLANATION OF PLATE 86
All figures ×9

FIG. *1-3*—*Parafusulina bösei* Dunbar & Skinner. *1*, Axial section; Hypotype; U.S.C. 3135. *2*, Equatorial section; hypotype; U.S.C. 3136. *3*, Axial section; hypotype; 3137.
4-7—*Parafusulina communis* Knight, n. sp. *4*, Equatorial section; paratype; U.S.C. 3138. *5*, Axial section; holotype; U.S.C. 3139. *6*, Tangential slice showing cuniculi; U.S.C. 3138. *7*, Axial section; paratype; U.S.C. 3140.
8,9—*Parafusulina* cf. *P. schucherti* Dunbar & Skinner. *8*, Equatorial section. *9*, Axial section.

wide. The form ratio varies considerably in the two specimens measured, reaching a value of from 2.5 to 3.5 in the 6th volution. Axial profile remains constant after the first two pointed poles.

The range in outside diameter of the spherical to subspherical proloculus is 350 to 475 microns, averaging 412 for 4 proloculi. The shell expands uniformly and gives a loosely coiled appearance in axial section.

The spirotheca is schwagerine with a moderately coarse keriotheca. It is 40 to 50 microns thick in the 1st and reaches a maximum of 125 to 150 in the 5th volution.

Approximately 20 septa are present in the 2nd volution and this number increases to 34 in the 6th whorl. Folding extends the entire shell length and shows a definite tendency toward triangular axial loops.

No chomata are present and the tunnel is narrow and irregular. A strong band of axial filling is present along the axis in all except the outer 2 whorls.

poles and there is a rapid change to widely rounded poles in the mature volutions. The outside diameter for the proloculus of the axial section illustrated is about 250 microns.

Some phrenothecae are developed sporadically throughout the shell. The wall is typically schwagerine with a coarsely alveolar keriotheca.

Measurements, in mm.

	Half length	Radius vector	Form ratio
1.	0.37	0.22	1.7
2.	—	0.37	—
3.	1.37	0.62	2.2
4.	2.25	0.82	2.7
5.	4.00	1.12	3.6
6.	5.00?		

Remarks.—This form may be a *Parafusulina*. A few poorly developed cuniculi have been seen in material that may belong to this genus. It seems to have affinities with *S. ellipsoides* Grozdilova.

Measurements of *Schwagerina retusa*, n. sp., in mm.

	Half length		Radius vector		Form ratio		Septal count	
1.	0.55	0.50	0.32	0.20	1.7	2.5	—	11
2.	0.87	0.75	0.50	0.32	1.8	2.3	22	21
3.	1.37	0.92	0.70	0.45	2.0	2.0	32	24
4.	2.12	1.87	1.00	0.62	2.1	3.0	32?	30
5.	3.30	3.12	1.37	0.87	2.4	3.6	35?	32
6.	4.00	3.62	1.62	1.05	2.5	3.5		34

Remarks.—*Schwagerina retusa*, n. sp., is much shorter than *Parafusulina diabloensis* Dunbar & Skinner, although there is a resemblance in general appearance and form ratio. Axial filling is much less concentrated in *P. diabloensis* and there is a striking dissimilarity in sagittal sections.

Occurrence.—Found about 200 feet from top of section 1 in a twenty foot interval and in the bottom one third of section 2.

Occurrence.—In bottom one-third of both intervals.

Schwagerina sp. A
Pl. 85, fig. 1

Only one good axial section was obtained of this species but for the sake of completeness it is illustrated and its measurements tabulated.

Individuals of this group are from 10 to 10.5 mm. long at the 6th volution and 2.2 to 2.5 mm. wide. They are cylindrical with widely rounded poles and convex lateral slopes. Their form ratio is near 4.0 for the last volution. The first 4 whorls have pointed

Genus Pseudofusulina
Dunbar & Skinner, 1931

Pseudofusulina lativentra
Knight, n. sp.
Pl. 85, fig. 2–6

Shells of *Pseudofusulina lativentra* are medium sized, fusiform, have convex lateral slopes, slightly curved axis of coiling, and roundly pointed poles. Individuals of 5 volutions are 6.8 to 8.4 mm. long and 2.4 to 3.4 mm. wide. The form ratio of the first 3 volutions is near 2.0 while the outer whorls are more nearly 3.0. Little change occurs in axial profile during growth.

The proloculus of these shells is large, averaging 470 microns in outside diameter for 6 individuals. It is usually about 50 microns in thickness and varies in shape between subspherical and spherical. The shell is loosely coiled, and expands uniformly.

Chamber heights increase gradually poleward.

The spirotheca is initially about 50 microns thick and reaches a value of 100 or more in the outer whorls. It has a very coarsely alveolar keriotheca and a distinct tectum.

Folding extends the length of the shell and forms arch-like axial loops. In tangential slices, chamberlets are formed that are slightly elongated.

The tunnel is not bordered by chomata and is rather narrow. Only sporadic secondary filling is developed.

is 3.6 in the last whorl. The shell retains essentially the same axial profile during growth.

Outside diameters for two spherical proloculi vary from 225 to 250 microns. The shell is somewhat tightly coiled in the first 3 volutions, after which it expands uniformly. Chamber heights become only slightly higher toward the poles.

The spirotheca is schwagerine with a distinct tectum and a coarsely alveolar keriotheca. A thickness of 100 to 115 microns occurs in the 6th to 7th whorl.

Folding extends the entire length of the

Measurements of *Pseudofusulina lativentra* n. sp., in mm.

	Half length			Radius vector			Form ratio			Septal count		
1.	0.67	0.45	0.65	0.37	0.32	0.50	1.8	1.4	1.3	12	12	14
2.	1.30	0.90	1.25	0.67	0.50	0.77	1.9	1.8	1.6	21	19	24
3.	2.17	1.50	2.25	0.90	0.75	1.02	2.4	2.0	2.2	30?	26	33
4.	3.75	2.30	3.10	1.20	0.95	1.37	3.1	2.4	2.3	—	—	32
5.		3.37	4.17		1.17	1.67		2.9	2.0?			—

Remarks.—This species is easily distinguished from the rest of the assemblage by its large proloculus, few volutions and an extremely loosely coiled appearance. *Pseudofusulina lativentra*, n. sp., has a thicker spirotheca and a much lower form ratio than *P. kiangsuensis* Chen, 1934, which also has a very large proloculus.

Occurrence.—Found in the upper two-thirds of both sections, but not in the top 50 to 100 feet.

Genus Parafusulina
Dunbar & Skinner, 1931
Parafusulina apiculata
Knight, n. sp.
Pl. 85, fig. 7–10

Tests of this species are large, elongate-fusiform, have evenly convex lateral slopes, a straight axis of coiling and bluntly pointed poles. One individual of 8 volutions is 9.6 mm. long and 2.6 mm. wide. The form ratio

test and cuniculi have been observed in tangential slices believed to belong to this species.

Small chomata are found bordering the tunnel of the first 2 or 3 volutions. The tunnel is narrow in the first 3 whorls and then widens rapidly in the volutions that follow. Secondary filling is irregularly located in the poles of all but the last two volutions.

Remarks.—*P. apiculata*, n. sp., can be distinguished from *P. shaksgamensis* Reichel by its elliptical profile, its smaller proloculus, and less axial filling. *P. shaksgamensis* is also longer than this species.

Occurrence.—Restricted to the uppermost parts of both sections, although it is never abundant.

Parafusulina bösei
Dunbar & Skinner
Pl. 86, fig. 1–3

Parafusulina bösei Dunbar & Skinner, 1937,

Measurements of *Parafusulina apiculata*, n. sp., in mm.

	Half length		Radius vector		Form ratio		Septal count
1.	0.30	0.27	0.20	0.15	1.5	1.8	8
2.	0.55	0.42	0.28	0.20	1.9	2.1?	19
3.	1.00	0.62	0.42	0.27	2.4	2.3?	23
4.	1.37	1.05	0.55	0.42	2.5	2.5	25
5.	2.00	1.87	0.80	0.57	2.5	3.3	24
6.	3.12	3.00	1.05	0.77	3.0	3.9	
7.		3.75		1.05		3.6	
8.		4.80		1.32		3.6	

Univ. Texas Bull. Bur. Econ. Geol. no. 3701, vol. 3, pt. 2, p. 679, pl. 73, fig. 1–9.

Specimens referred to this species have 5 to 6 volutions and a length of 8 to 8.4 mm. and a width of 2.76 to 2.4 mm. They are slightly inflated-fusiform, have gently concave lateral slopes, a straight axis of coiling, and show well rounded poles in the mature volutions. The form ratio increases from 1.65 to 3.0 in the outer whorls. During growth the profile changes from sharply pointed fusiform in the first 3 whorls to blunt poles at maturity.

The spherical to irregular proloculus averages 400 microns in the three individuals measured and is thick-walled, commonly showing a thickness close to 50 microns. The shell expands uniformly and the heights of the chambers increase gradually poleward.

The spirotheca is schwagerine and coarsely alveolar with a thickness of from 35 to 110 microns.

Measurements of *Parafusulina bösei* Dunbar & Skinner, in mm.

	Half length		Radius vector		Form ratio		Septal count	
1.	0.37	0.50	0.22	0.30	1.6	1.7	19	14
2.	0.77	0.75	0.40	0.45	1.9	1.7	28	23
3.	1.35	1.25	0.65	0.63	2.1	2.0	26	26
4.	2.75	1.75	0.90	0.90	3.0	1.9	28	32
5.	4.00	2.75	1.20	1.07	3.3	2.6	37	34
6.		3.67		1.38		2.7	36	

The first volution contains from 14 to 19 septa and there is a gradual increase to about 35 in the 5th and 6th whorls. Septal folding is intense and high. Cuniculi have been observed in material believed to belong to this species, and there are slight indications of phrenothecae locally in the outer volutions.

The tunnel is of moderate width, but is not distinct in thin section. Chomata are not present, although there is a trace of axial filling in the poles of the first volutions.

Remarks.—These forms are somewhat shorter and thicker than the types of *P. bösei* and show a little more closely coiled test; further study may prove them to be a new variety. The types are from the Word formation of Texas, about 400 feet above the base.

Occurrence.—See Text-fig. 3 for location in respect to measured sections.

PARAFUSULINA COMMUNIS
Knight, n. sp.
Pl. 86, fig. 4–7

Shells assigned to *P. communis* are large, elongate-fusiform to subcylindrical, possess evenly convex lateral slopes, a straight axis of coiling and bluntly rounded poles. Mature specimens of 6 to 6½ volutions are 8.5 to 9.0 mm. long and 2.5 to 3.0 mm. wide. Their form ratio is 1.5 to 2.0 in the 2nd volution and increases to 3.0 in the last whorl.

The average outside diameter for 6 proloculi is 300 microns, although a variation from 250 to 375 occurred. The proloculus shape, when not distorted, is spherical, but the majority of the specimens observed are irregularly crushed in the first few volutions. The shell is loosely coiled after the first whorl and expands uniformly. Chamber heights increase moderatly poleward.

A distinct tectum is present along with a coarsely alveolar keriotheca, however, the keriotheca is generally in a poor state of preservation. The spirotheca is about 25 microns thick at the first volution and reaches a maximum of 105 to 120 in the 5th.

Folding extends the entire length of the shell and cuniculi are developed in at least the outer 2 or 3 volutions. Phrenothecae are

Measurements of *Parafusulina communis*, n. sp., in mm.

	Half length			Radius vector			Form ratio			Septal count
1.	0.50	0.50	0.40	0.32	0.35	0.27	1.5	1.4	1.5	10
2.	1.02	1.00	0.65	0.50	0.52	0.42	2.0	1.9	1.5	24
3.	1.27	1.75	0.85	0.70	0.75	0.60	1.8	2.3	1.4	25
4.	2.00	2.50	1.82	0.90	0.97	0.80	2.2	2.6	2.3	30
5.	3.00	3.75	2.87	1.37	1.17	1.05	2.2	3.2	2.7	30
6.	4.25	4.50	3.87	1.60	1.50	1.27	2.7	3.0	3.0	34?

well developed in the outer whorls, but no pattern is followed as to location.

The tunnel is narrow, when observable, and is not bounded by chomata. Axial filling is not strong and is largely located in the poles of the inner 3 volutions.

Remarks.—Shell has a shape similar to *Fusulina subcylindrica* Deprat, although it lacks this species' high form ratio of 4.2 to 5.0.

Occurrence.—Ranges throughout all but the extremes of both measured sections.

PARAFUSULINA cf. P. SCHUCHERTI
Dunbar & Skinner
Pl. 86, fig. 8,9

? *Parafusulina schucherti* DUNBAR & SKINNER, 1937, Univ. Texas Bull. Bur. Econ. Geol., no. 3701, vol. 3, pt. 2, p. 672; pl. 64, fig. 9–12.

Members of this species are moderately large, thickly fusiform, have strongly convex lateral slopes, a straight axis of coiling and rather sharply pointed poles. Shells of 6 volutions are around 8 mm. long and 2.5 to 3.1 mm. wide. Their form ratio is initially about 1.5, is near 2 in the 3rd volution and reaches a value from 2.5 to 3.2 at the 6th. A slight elongation of the axial profile occurs in the outer volutions.

The spirotheca consists of a tectum and a coarsely alveolar keriotheca. It is 50 to 65 microns thick in the 2nd volution, 110 in the 5th and reaches a maximum of 125 in the 6th. Septal folding reaches the entire length of the shell and a few poorly developed cuniculi have been seen. Chomata are not present along the irregularly narrow tunnel. Two spots of axial filling are created by the coalescing of the deposits in the first 4 volutions.

Remarks.—These forms differ from typical *P. schucherti* in having a greatly reduced number of septa per whorl. Other than this, they seem to be identical with those from Texas.

Occurrence.—See Text-fig. 3.

PARAFUSULINA SHAKSGAMENSIS CRASSIMARGINATA Knight, n. var.
Pl. 87, fig. 1–3

Members of this species are of moderate size, elongate-fusiform to cylindrical in shape, show evenly convex lateral slopes, and have a straight axis of coiling. Shells of 6 to 7 volutions are from 9 to 11 mm. in length and 3 to 3.5 mm. wide. The form ratio increases gradually during growth from approximately 2.0 to 3.0 in the 6th volution.

Measurements of *Parafusulina* cf. *P. schucherti* Dunbar & Skinner, in mm.

	Half length		Radius vector		Form ratio		Septal count
1.	0.50	0.42	0.32	0.27	1.5	1.6	—
2.	1.00	0.87	0.52	0.47	1.9	1.8	19
3.	1.50	1.37	0.77	0.67	1.9	2.0	23?
4.	2.00	2.12	1.05	0.85	1.9	2.5	26
5.	3.00	3.07	1.25	1.05	2.4	2.9	27
6.	4.00	4.07	1.57	1.27	2.5	3.2	31

The outside diameter of the subspherical proloculus varies from 275 to 325 microns and is approximately 50 microns in thickness. The shell is somewhat tightly coiled from the first 2 volutions, after which it expands uniformly. Only a slight increase takes place in the height of the chambers from the equator to the poles.

One individual of 7 volutions has a form ratio of 3.5 in the last whorl. Throughout growth the axial profile is predominantly a sharply pointed ellipse, although the last 2 whorls become, at times cylindrical through the middle portion.

The thin-walled proloculus, 25 to 30 micons thick, ranges in size from 275 to 425

Measurements of *Parafusulina shaksgamensis crassimarginata*, n. var., in mm.

	Half length			Radius vector			Form ratio			Septal count	
1.	0.40	0.37	0.55	0.20	0.22	0.42	2.0	1.7	1.3	17	14
2.	0.62	0.77	1.15	0.35	0.37	0.62	1.8	2.1	1.9	27	25
3.	1.12	1.32	1.75	0.52	0.55	0.90	2.1	3.2	1.9	34	28
4.	1.87	1.90	2.82	0.77	0.80	1.20	2.4	2.4	2.7	39	37
5.	3.00	3.00	4.25	1.00	1.12	1.50	3.0	2.7	2.8	43	35
6.	3.90	4.27	5.60	1.27	1.42	1.77	3.0	3.0	3.1	40?	
7.	4.87	—		1.40	1.77		3.5	—			

microns and averages 350. The shell is loosely coiled and expands uniformly. Chamber heights are uniform in the first 4 volutions after which there is a gradual increase from the equator to the pole.

Both tectum and keriotheca are well developed and the spirotheca increases in thickness from 35 to 50 microns to 75 to 140 in the outer whorls.

Septa are numerous starting with about 15 per whorl and increasing to a value near 40. Folding is high and extends the length of the shell. Cuniculi are found in at least the outer three whorls.

The tunnel is narrow in all stages of growth. Axial filling is present in the ends of all volutions except the outer 2.

Remarks.—This variety differs from the typical *P. shaksgamensis* in having lighter axial filling, a much thicker spirotheca at maturity, and is somewhat shorter. Dunbar & Skinner (1937, pl. 66, fig. 10) illustrate a section of *S. franklinensis* that strongly resembles this form. However, the lack of cuniculi eliminate it from consideration. The types of this species are from the upper Artinskian, Kashmir.

Occurrence.—See Text-fig. 3. It is abundant in sample R.K.63.

PARAFUSULINA VISSERI Reichel
Pl. 87, fig. 4

Parafusulina visseri REICHEL, 1940, Unterpermische Fusuliniden aus dem Karakorum und dem Aghil-Gebirge. *In:* RENZ, & REICHEL, Die paläontologischen Ergebnisse der Expeditionen 1935; I.—Die paläozoischen Faunen von 1935. *In:* VISSER & VISSER-HOOFT, Wissenschaftliche Ergebnisse der niederlandischen Expeditionen in den Karakorum und die angrenzenden Gebiete in den Jahren 1922, 1925, 1929/30 und 1935. Bd. 3, Fazz. 1, p. 112; pl. 24, fig. 1,2.

Tests of this species are large, slightly inflated-fusiform, have convex lateral slopes, and a straight axis of coiling. Individuals of 8 to 9 volutions are 12 to 15 mm. long and 3.6 to 4.3 mm. wide. The form ratio remains close to 2.0 for the 1st 4 volutions, then increases gradually to 3.3 in the 8th whorl. The first 6 volutions are pointed fusiform, then they become bluntly rounded.

Outside diameters of 3 spherical proloculi range from 425 to 500 microns and they all have a wall thickness near 35 microns. The shell is loosely coiled, expands uniformly and shows only a slight increase in chamber heights near the poles.

The spirotheca exhibits a distinct, but thin, tectum and a coarse keriotheca. Its greatest thickness is reached in the next to last whorl where it is near 120 microns. Initially it is 35 to 40 microns thick and increases only slightly until the 5th whorl.

Septa reach 34 per whorl in the 6th volution. Folding extends the length of the shell, is confined mostly to the lower half of the septa, and produces flattened triangular to rectangular loops in axial section. After the 6th volution the folding becomes vesicular in the pole regions. Phrenothecae are well developed in the outer whorls only.

The tunnel angle is of moderate width, although it is not bordered by chomata Axial filling is intense and is concentrated in two triangular-shaped areas along the axis, but does not extend into the last few volutions.

Remarks.—The types of this species are from the upper Artinskian (Middle Permian) of Kashmir.

Occurrence.—May range through a much larger interval than shown on the chart of Text-fig. 3.

PARAFUSULINA VISSERI LATA Reichel
Pl. 87, fig. 5,6

Parafusulina visseri REICHEL var. *lata* REICHEL, 1940, Unterpermische Fusuliniden aus dem Karakorum und dem Aghil-Gebirge. *In:* Renz,

Measurements of *Parafusulina visseri* Reichel, in mm.

	Half length				Radius vector				Form ratio				Septal count
1.	0.40	0.42	—	0.50	0.27	0.30	0.40	0.35	1.4	1.4?	—	1.4	12
2.	0.80	0.65	1.02	1.13	0.40	0.45	0.55	0.47	2.0?	1.5?	1.8	2.4	19
3.	1.05	1.10	1.62	2.05	0.57	0.60	0.80	0.72	1.8?	1.8	2.0	2.8	27
4.	1.75	1.52	2.62	2.50	0.75	0.77	—	0.98	2.3	2.0	—	2.6	33
5.	2.40	2.22	4.00	3.20	1.00	1.20	—	1.2	2.4	1.9	—	1.7	30
6.	3.57	2.37	5.76	4.45	1.27	1.52	1.75	1.55	2.8	2.2	3.3	2.9	34
7.	4.75	4.42	—	5.75	1.60	1.87	—	1.87	3.0	2.4		3.1	
8.	5.90			6.44	1.80			2.15	3.3			3.0	
9.				7.55				—					

& Reichel, Die palänotologischen Ergebnisse der Expeditionen 1935: Die paläozoischen Faunen von 1935. In VISSER, P. C., and VISSER HOOFT, J., Wissenschaftliche Ergenbisse der niederlandischen Expeditionen in der Karakorum und die augrenzenden Gebiete in den Jahren 1922, 1925, 1929/30 und 1935. Bd. 3, Fazz. 1, p. 114; pl. 24, fig. 3,4.

These forms are large, cylindrical, develop concave lateral slopes in the outer volutions, have a nearly straight axis of coiling and bluntly rounded poles at maturity. Individuals of 6 volutions are 8 mm. long and reach 11 mm. in the 7th. During growth the form ratio increases from 2.0 to 2.4 in the first volution to 3.2 in the 7th. The axial outline also becomes progressively more rounded at the poles.

The outside diameter of 2 spherical proloculi varied from 250 to 275 microns. Shell expansion is uniform for the loosely coiled test. Chamber heights increase rapidly in the poles of the mature volutions.

The spirotheca consists of a tectum and a coarsely alveolar keriotheca, gradually increasing from a thickness of 25 microns to about 100 microns in the 5th and 6th whorls.

Due to the similarity of this species with *S. moormanensis*, there is some doubt as to whether an equatorial section of this form has been obtained. The true picture is also confused by the fact that Reichel fails to illustrate an equatorial section for this variety. However, a septal count on a sagittal section that may belong to this variety gives 11, 18 and 29 septa per whorl for the 1st, 3rd and 5th volutions. Septal folding extends the length of the shell, becomes peculiarly vesicular in the outer whorls and develops high, rectangular axial loops in the last 2 whorls. Poorly developed cuniculi are seen in the outer volutions.

The tunnel is not clearly defined and where seen it is of moderate width. Chomata do not border the tunnel and secondary filling follows no pattern.

Remarks.—The types of this species are found in the upper Artinskian of Kashmir.

Occurrence.—Abundant in sample R.K.13, but is also found on either side of this sample, in section 2 near the bottom and in a zone about 200 feet from the top.

Measurements of *Parafusulina visseri lata* Reichel, in mm.

	Half length		Radius vector		Form ratio		Septal count
1.	0.42	0.40	0.27	0.27	1.5	1.5	11
2.	0.75	1.00	0.37	0.42	2.0	2.4	16
3.	1.22	1.47	0.57	0.57	2.1	2.6	18
4.	1.90	2.25	0.75	0.82	2.5	2.7	23
5.	2.75	3.25	1.07	1.12	2.6	2.9	29
6.	4.07	4.00	1.32	1.50	3.1	2.7	
7.	5.52		1.72		3.2		

PARAFUSULINA sp. A
Pl. 87, fig. 7

The axial section illustrated is the only well oriented specimen that was obtained during this study. The shell is medium-sized, sub-cylindrical, has a straight axis of coiling and bluntly rounded poles. This one individual has 8 volutions, is 9.8 mm. long and 3.25 mm. wide. Its form ratio reaches a value near 3.0 in the 5th volution and retains it throughout. The first 4 volutions are pointed fusiform, after which the poles become progressively more rounded.

The proloculus is nearly spherical, thin-walled and has an outside diameter of 275 microns. The shell gives an appearance of being tightly coiled in the first 3 volutions, but this may be accentuated by the high axial loops. Chamber heights remain uniform throughout the shell except in the ex-

Measurements of *Parafusulina* sp. A, in mm.

	Half length		Radius vector		Form ratio	
1.	0.32	0.37	0.22	0.27	1.4	1.4
2.	0.60	0.65	0.35	0.37	1.7	1.7
3.	1.00	1.25	0.45	0.50	2.2	2.5
4.	1.52	1.62	0.62	0.65	2.4	2.5
5.	2.25	2.75	0.80	0.92	2.8	3.0
6.	3.15	3.82	1.02	1.17	3.1	3.3
7.	4.30		1.35		3.2	
8.	4.90		1.62		3.0?	

treme outer ends of each volution where a decided inflation occurs. This gives the shell a peculiar and distinctive axial profile.

The spirotheca is poorly preserved, but a strong tectum is present. Traces of what appears to be a moderately coarse alveolar structure are also present from place to place along the lateral slope. It is 50 microns thick in the first volution and reaches a maximum of 90 in the 6th.

No equatorial section was found that corresponds with these specimens and no information on septal count is available.

Septal folding extends the entire length of the shell and forms high arch-like loops in axial slices. Poorly developed cuniculi have been observed in tangential slices believed to belong to this species.

The tunnel is quite narrow where observed and is not bordered by chomata. Little or no axial filling is seen.

Occurrence.—Found in the bottom third of both sections, but never common.

PARAFUSULINA SUPERLATA
Knight, n. sp.
Pl. 88, fig. 1,4

These shells are large, fusiform to subcylindrical, have convex lateral slopes, a straight axis of coiling and pointed poles. The largest individual studied is 10.0 mm. long at 6½ volutions and 4.4 mm. wide. Its total length is slightly over 15 mm. The form ratio remains between 2 and 2.5 for all volutions after the first. Axial outline is constant during growth.

The average outside diameter of three subspherical proloculi is 275 microns. The variation in size is from 250 to 300. Shell expansion is uniform and chamber heights remain almost uniform from the equator to poles of each volution.

The spirotheca is thick, starting at about 60 microns and reaching a value of 125 microns in the 5th volution. A moderately coarse keriotheca and distinct tectum are present.

Folding extends the length of the test and produces characteristic triangular axial loops. Pendent loops have been noticed in the outer 2 whorls of a parallel section belonging to this species.

The tunnel is not clearly defined or bordered by chomata. A very strong band of secondary filling follows the axis in all whorls.

Remarks.—The most striking feature of this species is the thick and heavy axial deposit of secondary filling that extends the entire length of the test. Its shape is also different than *P. splendens* Dunbar & Skinner, the other large species found in these sections.

Occurrence.—See Text-fig. 3.

PARAFUSULINA SUBLINEARIS
Knight, n sp.
Pl. 87, fig. 8; Pl. 88, fig. 2,3,6

This form is a large, slender, thin-walled species of from 7 to 9 volutions with a length of about 15.0 mm. and a diameter slightly over 3.0 mm. The form ratio of the only

Measurements of *Parafusulina superlata*, n. sp., in mm.

	Half length			Radius vector			Form ratio			Septal count
1.	0.37	0.45	0.52	0.37	0.20	0.27	1.0	2.3	1.9	12
2.	1.12	1.02	1.20	0.57	0.42	0.47	2.0	2.5	2.5	19
3.	1.87	1.50	1.92	0.80	0.62	0.75	2.3	2.4	2.5	29
4.	2.50	2.12	2.60	1.10	0.85	1.05	2.3	2.5	2.5	35
5.	2.75	3.15		1.37	—		2.0			34
6.	4.12			1.75			2.3			
6¼.	5.00			2.20						

EXPLANATION OF PLATE 87
All figures ×9

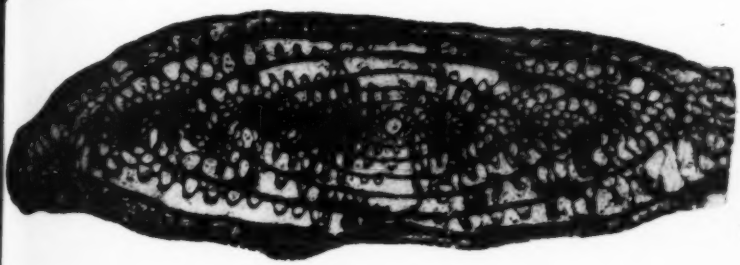
FIG. *1–3*—*Parafusulina shaksgamensis crassimarginata* Knight, n. var. *1*, Axial section; holotype; U.S.C. 3141. *2*, Equatorial section; paratype; U.S.C. 3142. 3, Tangential section showing well developed cuniculi; U.S.C. 3143.

4—*Parafusulina visseri* Reichel. *4*, Axial section; hypotype; U.S.C. 3144.

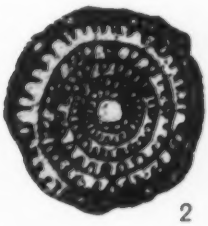
5,6—*Parafusulina visseri lata* Reichel. *5*, Equatorial section questionably included in this species; hypotype; U.S.C. 3135. *6*, Axial section; hypotype; U.S.C. 3146.

7—*Parafusulina* sp. A. *7*, Axial section.

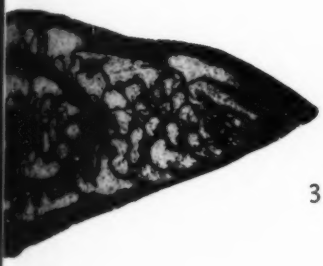
8—*Parafusulina sublinearis* Knight, n. sp. *8*, Equatorial section. paratype; U.S.C. 3148.



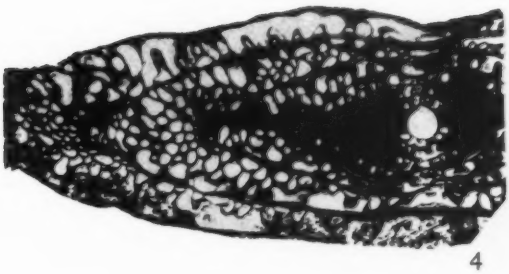
1



2

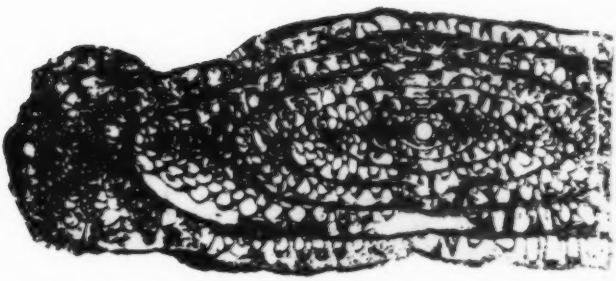


3

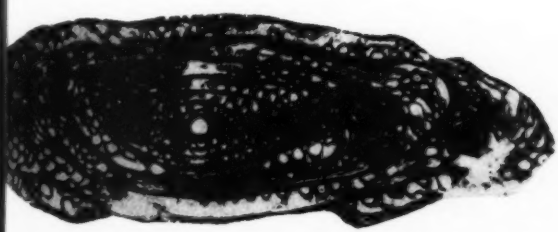


4

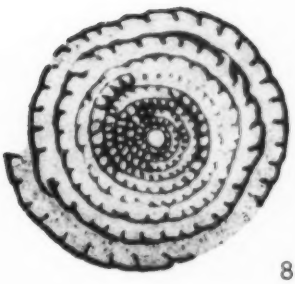
5



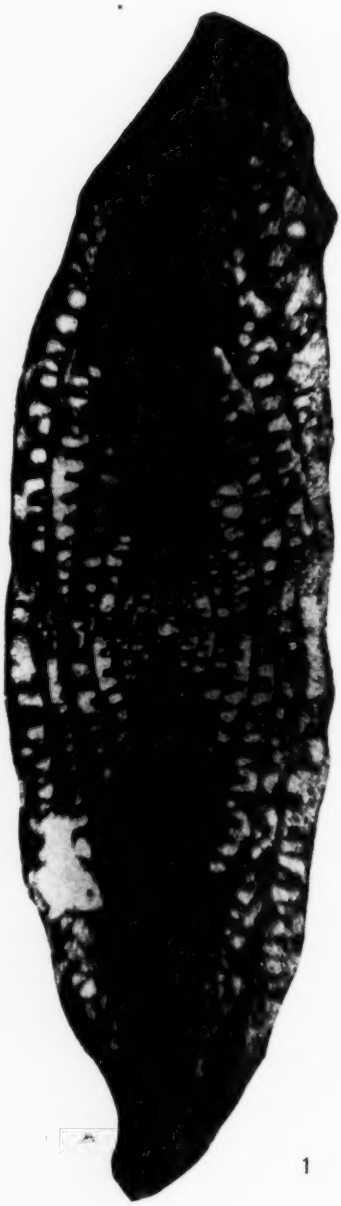
6



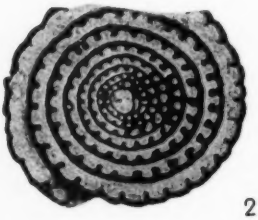
7



8



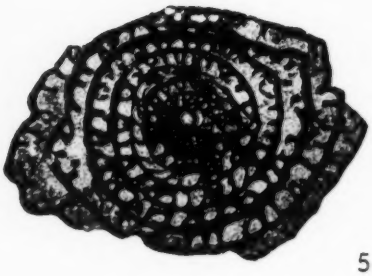
1



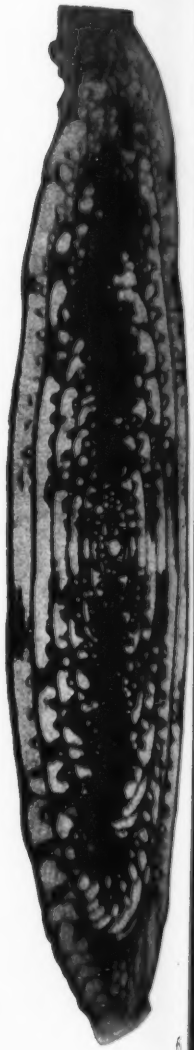
2

3

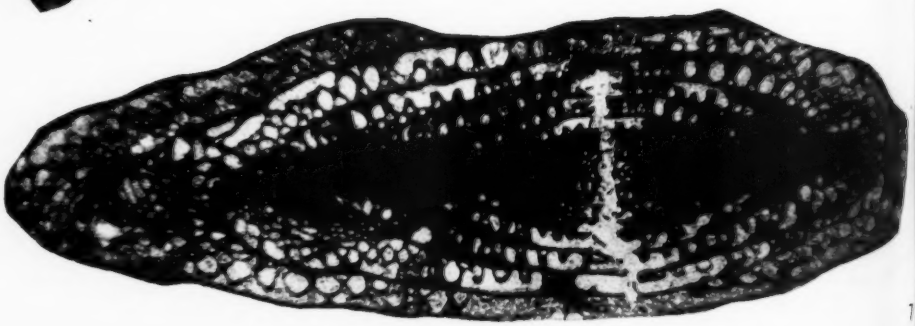
4



5



6



7

good axial section obtained reaches a figure of 4.8 in the 7th volution after an initial ratio of 1.7. The test is only very slightly inflated at the equator with the lateral slopes showing little tendency to become concave.

The proloculus outside diameter varies from 275 to 325 microns with an average of 287 microns. It is characteristically thin-walled and irregularly shaped. The shell expands uniformly and the chambers become progressively higher from the equator to the distinctly rounded poles.

The spirotheca is of the schwagerine type showing a strong keriotheca. The spirotheca is about 30 microns thick in the initial volutions and reaches a thickness of 75 in the 9th whorl.

Septa are numerous and low, increasing from around 10 in the 1st volution to 34 in the last whorl of the only individual found that had reached the 9th volution. Septal folding is low and not intense, giving a low arch-like appearance to the septal loops in axial sections. Folding extends the length of the shell. Strong cuniculi are found in at least the outer 3 whorls. Their development is shown by fig. 3 on Pl. 88.

The tunnel is approximately 50 degrees in the early volutions, although it widens rapidly to 70 degrees or so in the later whorls. Chomata are lacking, but a strong, linear band of axial filling follows the center of the shell.

Remarks.—*P. sublinearis*, n. sp., is closely related to *Schwagerina linearis* Dunbar & Skinner. It differs markedly from that species in having a smaller form ratio per whorl and especially in having cuniculi at a level of development usually found in members of the genus at stratigraphically higher positions. *P. peruana* Roberts is much shorter, has a thicker spirotheca, and slightly more septa per whorl. *P. shiptoni* Dunbar differs in having a smaller proloculus, more axial filling, and a form ratio of about 6.0.

The association of *P. sublinearis*, n. sp., with *T. secalicus oryziformis* Newell complicates the age determination for this species. The problem is best solved by placing both of these forms in the Wolfcampian and considering that they, like *S. linearis*, represent the highest subzone of this series in Nevada.

Occurrence.—Locality WHE-217 from the cherty limestone on the east flank of the second hill east of the contact between the Vinini formation and the conglomerate about 200 yards south of Nevada State Highway 20 in the NE/4 of Sec. 21, T. 22 N., R. 52 E., Eureka Co., Nevada.

Measurements of *Parafusulina sublinearis*, n. sp., in mm.

	Half length	Radius vector	Form ratio	Septal count		
1.	0.47	0.27	1.7	10	12	10
2.	0.80	0.37	2.2	17	17	18
3.	1.37	0.55	2.5	17	18	22
4.	2.25	0.72	3.1	24	22	28
5.	3.12	0.92	3.4	22	24	29
6.	5.25	1.17	4.5	23	26	33
7.	7.37	1.52	4.8	25?	29	30
8.						30
9.						34

PARAFUSULINA SPLENDENS
Dunbar & Skinner
Pl. 88, fig. 5,7

Parafusulina splendens DUNBAR & SKINNER, 1937, Univ. Texas Bull., Bur. Econ. Geol., no. 3701, vol. 3, pt. 2, p. 682; pl. 75, fig. 1–11.

EXPLANATION OF PLATE 88
All figures ×9

FIG. *1,4*—*Parafusulina superlata* Knight, n. sp. *1*, Axial section; holotype; U.S.C. 3149. *4*, Equatorial section; paratype; U.S.C. 3150.

2,3,6—*Parafusulina sublinearis* Knight, n. sp. *2*, Equatorial section; paratype; U.S.C. 3151. *3*, Tangential slice showing cuniculi; paratype; U.S.C. 3152. *6*, Axial section; holotype; U.S.C. 3153.

5,7—*Parafusulina splendens* Dunbar & Skinner. *5*, Equatorial section; hypotype; U.S.C. 3154. *7*, Axial section; hypotype; U.S.C. 3155.

A large elongate-fusiform species with convex lateral slopes, a straight to slightly curved axis of coiling and sharply rounded poles. The axial section illustrated, of 9 volutions, is 16 mm. long and 4.5 mm. wide. The form ratio is 2.0 for the 1st 4 whorls and then increases evenly to 3.6 at the last volution. The early whorls have sharper poles than do the mature ones.

The proloculus is probably spherical and measures approximately 300 microns. Expansion of the shell is uniform after the first few tightly coiled whorls. Chamber heights do not increase very much, even near the poles.

The spirotheca is schwagerine, reaching a thickness of 110 microns at the 6th volution.

Folding extends the length of the shell, producing high rectangular axial loops in the central portion of the test. Some phrenotheca occur, but no pattern is followed. Cuniculi are of moderate strength.

The tunnel angle is small and most shells seem to have been faulted in the equatorial plane. The explanation for this is not apparent. Secondary filling typical of the species is shown in axial slices.

Measurements of *Parafusulina splendens* Dunbar & Skinner, in mm.

	Half length	Radius vector	Form radio	Septal count
1.	0.37	0.25	1.5	19
2.	0.75	0.37	2.0	—
3.	1.12	0.55	2.0	—
4.	1.52	0.75	2.0	31
5.	2.37	1.00	2.4	36
6.	3.37	1.25	2.7	35
7.	4.50	1.55	2.9	—
8.	6.00	1.87	3.2	
9.	8.00	2.25	3.6	

Remarks.—The types are from 400 feet above the base of the Word formation, Glass Mountains, Texas.

Occurrence.—The fauna from the middle of the two measured sections contains large numbers of these forms.

REFERENCES

BACON, C. S., JR., 1948, Geology of the Confusion Range, west central Utah: Geol. Soc. Amer., Bull. vol. 59, p. 1027–1052.

CAMPBELL, G. S., 1951, Permian system of Millard Co., Utah: Intermountain Assoc. Pet. Geol., Guide-book Geol. Utah, no. 6, p. 63–65.

DUNBAR, C. O., 1939, Permian fusulines from Central America: Jour. Paleont., vol. 13, p. 344–348.

——, 1940, Type Permian: Amer. Assoc. Pet. Geol., Bull. vol. 24, p. 237–281.

——, & SKINNER, J. W., 1937, Permian Fusulinidae of Texas: Univ. Texas Bull., Bur. Econ. Geol., no. 3701, pt. 2, p. 523–825.

FRENZEL, HUGH, & MUNDORFF, M., 1942, Fusulinidae from the Phosphoria formation of Montana: Jour. Paleont., vol. 16, p. 675–684.

KING, PHILIP B., 1948, Geology of the southern Guadalupe Mountains, Texas: U. S. Geol. Surv., Prof. Paper 215, p. 179.

NEWELL, N. D., 1948, Key Permian section, Confusion Range, western Utah: Geol. Soc. Amer., Bull., vol. 59, p. 1053–1058.

SPENCER, A. C. 1917, The geology and ore deposits of Ely, Nevada: U. S. Geol. Surv., Prof. Paper 96.

THOMPSON, M. L., 1948, Studies of American fusulinids: Univ .Kansas Publ., Art. 1, 184 p.

——, & MILLER, A. K., 1944, The Permian of southernmost Mexico and its fusulinid faunas: Jour. Paleont., vol. 18, p. 481–504.

——, ——, 1949, Permian fusulinids and cephalopods from the vicinity of the Maracaibo basin in northern South America: Jour. Paleont., vol. 23, p. 1–24.

——, VERVILLE, G. J., & BISSELL, H. J., 1950, Pennsylvanian fusulinids of the south-central Wasatch Mtns., Utah: Jour. Paleont., vol. 24, p. 430–456.

——, WHEELER, H. E., & HAZZARD, J. C., 1946, Permian fusulinids of California: Geol. Soc. Amer., Mem. 17, 77 p.

JOURNAL OF PALEONTOLOGY, VOL. 30, NO. 4, P. 793–810, PL. 89–93, 1 TEXT-FIG., JULY 1956

FUSULINIDS OF THE DESMOINESIAN—MISSOURIAN CONTACT

M. L. THOMPSON, G. J. VERVILLE, AND D. H. LOKKE

University of Kansas, Lawrence; Stanolind Oil & Gas Co., Tulsa, Oklahoma; and University of Kansas.

ABSTRACT—Desmoinesian and Missourian fusulinids have long been considered quite distinct. The discovery of the new species *Fusulina fallsensis* in lower Missourian rocks associated with *Wedekindellina ultimata* extends the geologic range of the former genus. Other fusulinids from near this contact described in this paper include two new species of *Oketaella*, *O. lenensis* and *O. oscurensis*, one new species of *Wedekindellina*, *W. ardmorensis*, and one new species of *Triticites*, *T. winterensis*.

GENERAL CONSIDERATIONS

THE fusulinids of the type Desmoinesian section in Iowa (Thompson, 1934) include representatives of the genera *Fusulinella*, *Fusulina*, and *Wedekindellina*. An examination of their distribution within the Desmoinesian shows advanced *Fusulinella* near the base of the section, early *Fusulina* and *Wedekindellina* in the middle part of the section, and advanced *Fusulina* in its upper part. The *Fusulinella* in basal Desmoinesian rocks of Iowa is considered to be an advanced form of the genus and the containing rocks are correlated with the basal Desmoinesian rocks of New Mexico which contain late *Fusulinella* and primitive *Fusulina*. Furthermore, the highest *Fusulina* in the Desmoinesian rocks of Iowa, *F. eximia* Thompson, evidently is a late form of the genus and is one of its most advanced species in America. Therefore, type Desmoinesian rocks contain species of *Fusulina* ranging in age from near the beginning of the genus to the latest species previously known in America. The one possible occurrence of *Fusulina* outside Desmoinesian rocks in America is the single species described by Thompson (1948) as *F.? insolita* from the upper part of the Derryan of New Mexico. Since *Fusulina* occurs throughout the Desmoinesian and was considered restricted to the Desmoinesian, that part of the Pennsylvanian has been designated as the Zone of *Fusulina*.

The base of the Missourian is most commonly placed in Kansas (Moore, *et al.*, 1951) at the base of the Hepler sandstone of the Pleasanton group and immediately above the Memorial shale of the Marmaton group of the Desmoinesian. The general sequence of rocks at and near the Desmoinesian-Missourian contact in Kansas are shown diagramatically in the accompanying illustration (Text-fig. 1).

Prior to 1937, the highest fusulinid known in the Desmoinesian of the northern midcontinent was *Fusulina eximia* in the Cooper Creek limestone of Iowa and the lowest known in the Missourian was "*Triticites irregularis*" (Staff) from the Winterset. The discovery by Newell & Keroher in 1937 of *Wedekindellina ultimata* Newell & Keroher in the Bethany Falls is the only reported occurrence of fusulinids in the interval since. In other words, fusulinids have not been reported in the section between the Altamont limestone and the Bethany Falls limestone of the Kansas section and between the Cooper Creek limestone and the Bethany Falls limestone of the Iowa section. Furthermore, it has often been pointed out that this was a part of the section in which a marked change occurred between the fusulinid faunas of the Desmoinesian below and the Missourian above. The first major limestone unit above the lower Missourian Bethany Falls limestone, the Winterset limestone, contains a very prolific fauna of *Triticites* and is the first major *Triticites*-bearing rock unit in the Missourian of Kansas, Iowa, and Missouri. The remaining Upper Pennsylvanian fusulinid faunas are dominated by species of *Triticites*, and the Upper Pennsylvanian (Kawvian) is designated as the Zone of *Triticites*.

We prepared many thin sections of the Bethany Falls limestone in the Missouri and Kansas region near Kansas City and found numerous specimens of an undescribed species of *Fusulina* in association with the

abundant fauna of *Wedekindellina ultimata*. Almost simultaneous with this discovery, Dr. H. R. Downs of Shell Oil Company sent the senior author for consultation a number of thin sections of the same species of *Fusulina* associated with *W. ultimata* in the Bethany Falls near Kansas City.

Previously, we had obtained from the type section of the Lenapah limestone of Oklahoma (0–78) a fusulinid not previously described from this part of the Pennsylvanian. We are describing this as the new species *Oketaella lenensis*. Also, Thompson (1942) reported a fusulinid as *Triticites?* from the basal Coane formation of New Mexico which is from that part of the section between the formerly known fusulinid-bearing parts of the Desmoinesian and of the Missourian. We are describing this form as the new species *Oketaella oscurensis*.

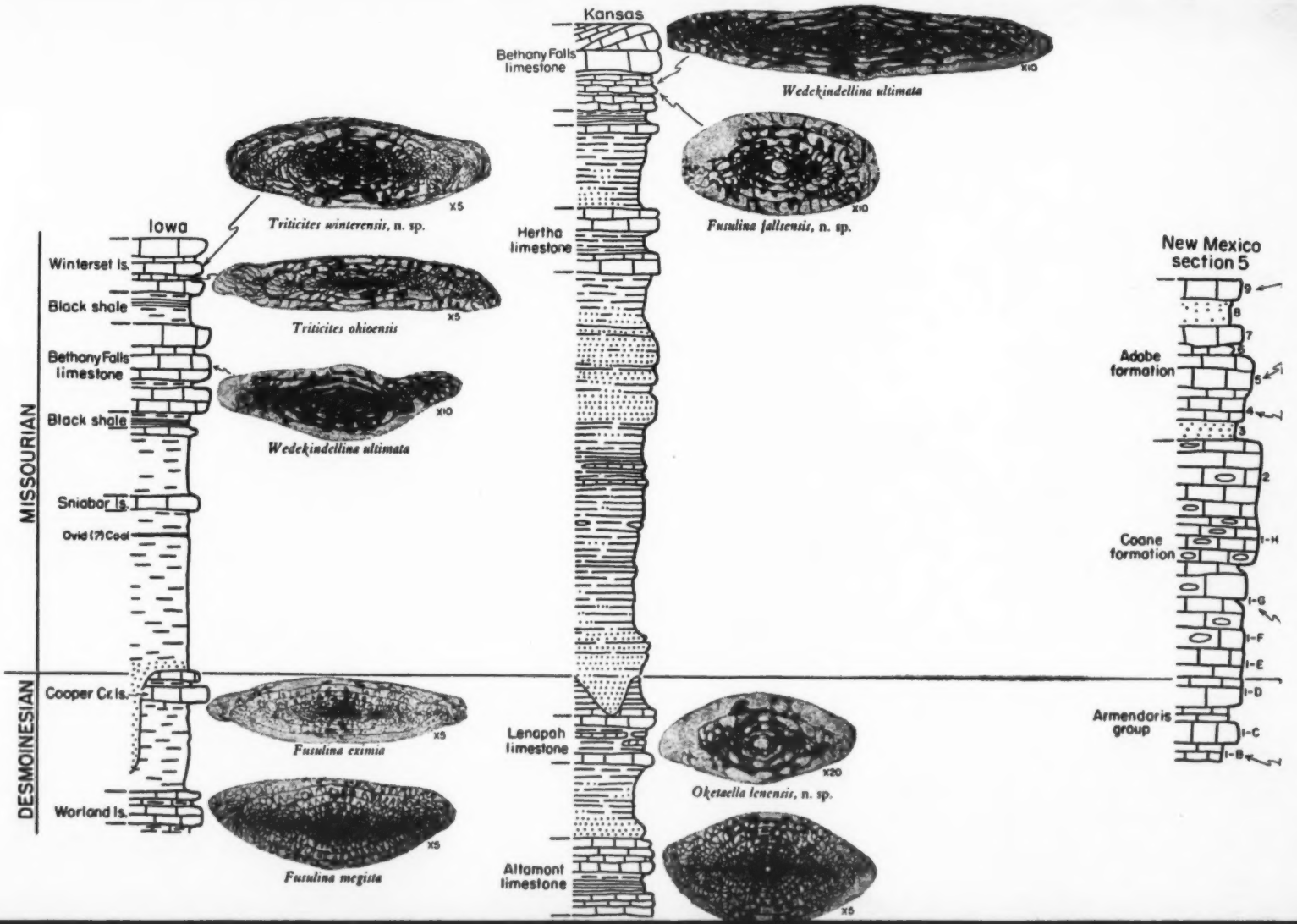
Several years ago we visited the type section of the Winterset limestone at Winterset, Iowa, and discovered an abnormally large fusulinid near the middle part of the Winterset in association with the abundant fusulinid species *Triticites ohioensis* Thompson. The former of these species has several unusual structural features for this part of the stratigraphic section, and we are describing it below as the new species *Triticites winterensis*.

Several wells examined in recent years from Texas penetrated rocks in which *Wedekindellina ultimata* was found to be associated in the samples with typical faunas of *Triticites*. It can not be proved that they are actually in association in the subsurface rocks, but it does suggest a possible common habitat. Also, Newell & Keroher (1937) reported scarce *Triticites* in the Bethany Falls with *W. ultimata*, but this latter association has not been found among many hundreds of thin sections of the same rocks at the same place. Although the latter two associations must be considered tentative and subject to confirmation, the relationships between the Desmoinesian and Missourian fusulinids are better understood since we now have *Fusulina* in association with *W. ultimata*. Although the fusulinid faunal differences between the Desmoinesian and the Missourian are not as sharply differentiated as formerly considered, many of the fusulinids near the contact are very distinctive and constitute excellent index fossils.

Many individuals have helped with this study: H. R. Downs sent specimens from Oklahoma and Kansas, R. V. Hollingsworth sent specimens from the subsurface of Texas, and C. W. Tomlinson gave information concerning the Confederate limestone. The following former students helped in many ways: Don Debout, Dave Bostwich, Wm. King, Walter Moore, Charles Pitrat, and George Sanderson. We especially wish to express thanks to the Stanolind Oil and Gas Company for permission to publish information obtained from some of their collections prepared by A. M. Pritzos and C. W. Martin. Special thanks are given for financial assistance from the General Research Fund of the University of Kansas and to the Research Committee of the University of Wisconsin for financial support given from funds furnished by the Wisconsin Alumni Research Foundation. This is published by permission of the Director of the Kansas Geological Survey and of the Director of the New Mexico Bureau of Mines and Mineral Resources.

LATE *Fusulina*

The genus *Fusulina* was established by Fischer de Waldheim in 1829 for species he named *F. cylindrica* and *F. depressa* in 1837 from the oölitic limestone at Mjatschkowo, Russia. The former species has since been made the genotype of *Fusulina*. The rocks at Mjatschkowo were later found to contain another altogether different fusulinid named *Fusulina simplex* by Schellwien (1908). The species *F. simplex* is referable to the genus *Triticites* Girty. Silvestri (1935) observed that material he had from Mjatschkowo was similar to the genotype of *Triticites* and not like the generally accepted interpretation of *Fusulina*, and he questioned the validity of *Fusulina* as then interpreted. However, the problem of the genotype of *Fusulina* s. s. was discussed in some detail later by Thompson (1936), at which time he interpreted *F. cylindrica* as being more closely similar to *F. eximia* Thompson from the upper part of the Desmoinesian of America than to *T. simplex* (Schellwien). Furthermore, he pointed out that both *F. cylindrica* and *Triticites simplex* may well be associated in the same rock at Mjatschkowo. Since the

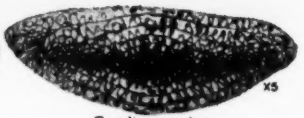

Kansas
Bethany Falls limestone
Hertha limestone
Lenapah limestone
Altamont limestone
Wedekindellina ultimata
x10
Fusulina fallisensis, n. sp.
x10
Iowa
MISSOURIAN
DESMOINESIAN
Winterset ls.
Black shale
Bethany Falls limestone
Black shale
Sniabar ls.
Ovid (?) Coal
Cooper Cr. ls.
Worland ls.
Triticites winterensis, n. sp.
x5
Triticites ohioensis
x5
Wedekindellina ultimata
x10
Fusulina eximia
x5
Fusulina megista
x5
Oketaella lenensis, n. sp.
x20
x5
New Mexico section 5
Adobe formation
Coone formation
Armendaris group
9
8
7
6
5
4
3
2
I-H
I-G
I-F
I-E
I-D
I-C
I-B

DESMOINESIAN

Cooper Cr. ls.

Fusulina eximia x5

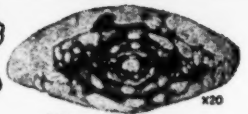
Worland ls.



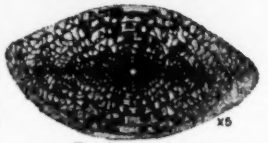
Fusulina megista x5

Lenapah limestone

Altamont limestone



Oketaella lenensis, n. sp. x20



Fusulina megista ? x5

Armendaris group

I-D

I-C

I-B

New Mexico, section 24

Adobe formation

26

25b

25a

24

23

22

21

20

Coane formation

19

18

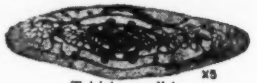
17

16

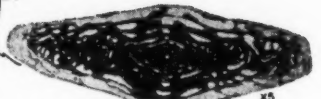
15

14

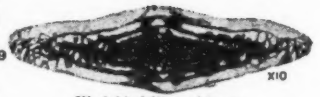
Triticites wellsi x5



Triticites wellsi x5

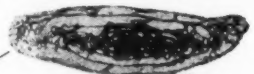


Wedekindellina ultimata x5



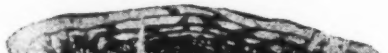
Wedekindellina ultimata x10

Triticites cf. *T. nebraskensis* x5



Triticites wellsi x5

Triticites, n. sp. x5



New Mexico, section 31

Adobe formation

117

116

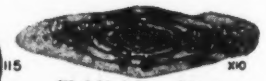
115

114

113

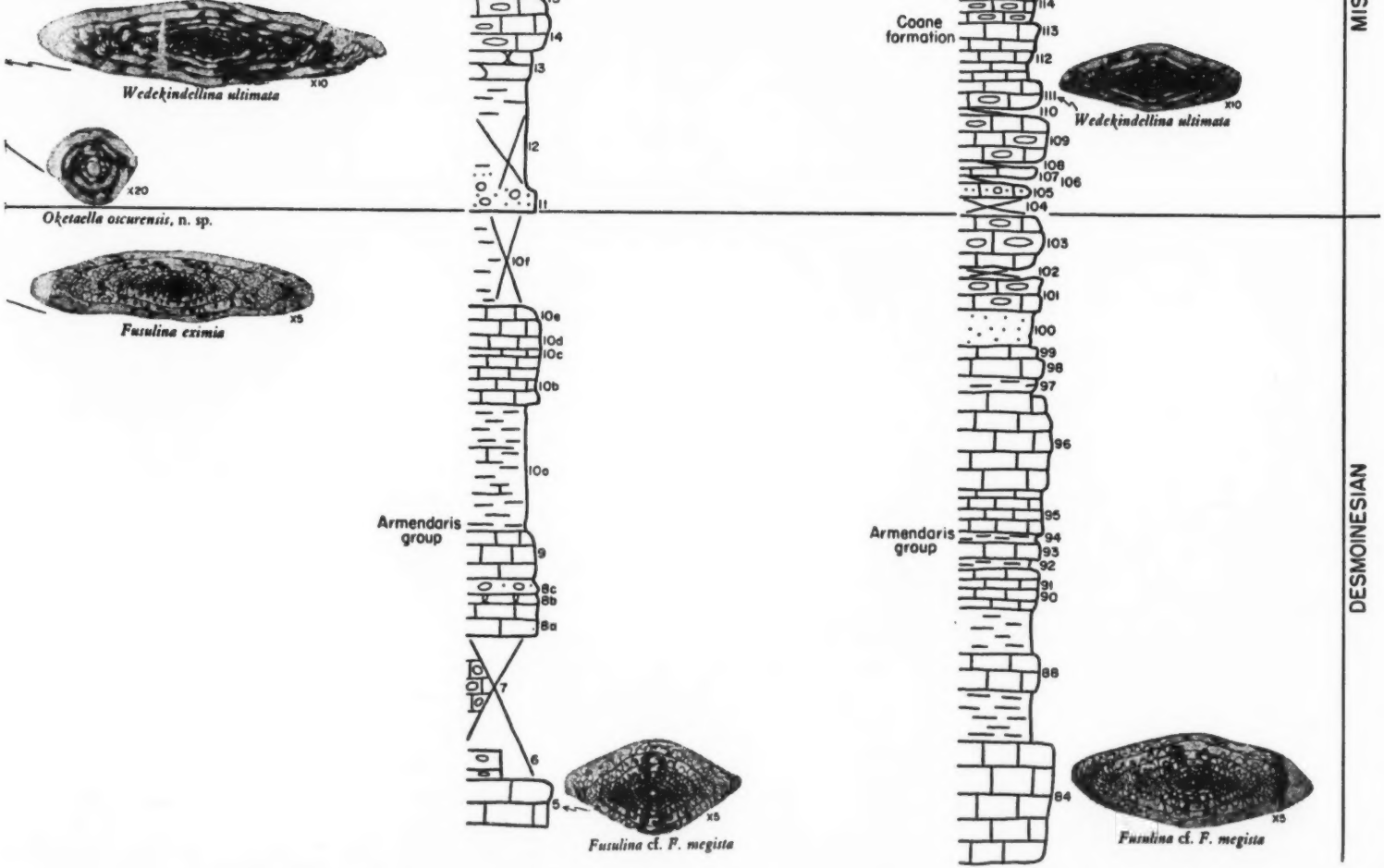
Coane formation

Triticites, sp. x5



Wedekindellina ultimata x10

MISSOURIAN



TEXT-FIG. *1*—Diagrammatic illustration of rocks near the Desmoinesian-Missourian contact in Iowa, Kansas, and New Mexico, with illustrations of some fusulinids. Vertical scale = 1:480.

shell of *T. simplex* is so nearly like lower Missourian *Triticites* of America, particularly those of the lower Canyon of Texas, the Mjatschkowo beds with *Triticites* are interpreted as being post-Desmoinesian in age. The close similarity of the Bethany Falls species described below as *Fusulina fallsensis*, n. sp., and *F. cylindrica* Fischer de Waldheim would seem to suggest a closely similar age for the basal Missourian rocks of America and the Moscovian at Mjatschkowo. This correlation is further suggested by the possible association of *Wedekindellina ultimata* with primitive *Triticites* in the subsurface of Texas.

Some further evidence of the age relationships between the American late Desmoinesian *Fusulina* and lower Missourian *Fusulina* and the Russian species *F. cylindrica* relate to their spirothecal structures, axial fillings, and erratic shell growth. The spirotheca of *F. cylindrica* is composed of the tectum, a porous diaphanotheca, and thin to erratic tectoria. Similarly, the spirotheca of *F. eximia* and that of the new Missourian form here described as *F. fallsensis* is composed of the tectum and diaphanotheca and irregular tectoria. *F. cylindrica* has light axial fillings and indefinite chomata. In comparison, *F. eximia* has low chomata and only small axial fillings, but *F. fallsensis* has definite axial fillings and relatively small chomata. The proloculus of *F. cylindrica* and that of *F. fallsensis* are relatively very large and are highly irregular in shape. Furthermore, the shells of both are irregular in shape, but that of *F. cylindrica* is much more highly elongate. The preponderance of evidence indicates that *F. fallsensis* is more nearly a typical *Fusulina* than are most other American species. It further indicates that *F. fallsensis* is even more primitive stratigraphically than is *F. cylindrica*. Although it is fully realized that exact age correlation of rocks almost around the world is not considered possible even with the fusulinids, it does seem that the limestones of the Mjatschkowo quarry are of about the same age as the Kansas City group of the midcontinent area and the lower Canyon of Texas. This may be a conservative estimate of the age of *F. cylindrica*, for it may be even slightly younger than this estimate.

LATE *Wedekindellina*

The genus *Wedekindellina* was established by Dunbar & Henbest in 1933 with *Fusulinella euthysepta* Henbest from the Cherokee of Illinois as the genotype. *Wedekindellina* is very abundant in the lower Desmoinesian of Iowa and in lower Desmoinesian rocks over a wide area in central United States from Ohio on the east to at least Idaho and Arizona on the west. The oldest species of the genus is *W. matura* Thompson in the Youghall formation of Colorado and Utah and in lower Desmoinesian rocks of Utah and Arizona. Until 1937, *Wedekindellina* was known only from the lower Desmoinesian and that part of the section was referred to as the Subzone of *Wedekindellina*. Newell & Keroher described *W. ultimata* in 1937 from the Bethany Falls limestone of Missouri and Kansas and extended the range of the genus into lower Missourian rocks.

The true taxonomic position of the fusulinid *Wedekindellina ultimata* has been the subject of discussion on several occasions. This species has a general shell shape almost identical to that of Cherokee species of *Wedekindellina*, general shell size comparable to them, closely spaced septa as they do, and heavy axial fillings like theirs. However, its septa are almost plane to broadly fluted across the central part of the shell and are fluted about half the height of the chambers in the polar quarters of the shell. As was pointed out by Newell & Keroher, *W. ultimata* resembles the form described by Doutkevitch (1934) as *Fusulinella uralica* Doutkevitch from the upper part of the Moscovian in the subsurface of the Middle Urals of Russia.

It is obvious that the fluted septa of *Wedekindellina ultimata* indicate that it is more advanced than the typical Desmoinesian forms of the genus. If the lack of septal fluting were the main characteristic of the genus *Wedekindellina*, perhaps this species should be referred to a different genus. The species is very widespread geographically and has been recognized in great abundance at the same general stratigraphic position near the base of the Missourian at many places in New Mexico, in eastern Wyoming, in the subsurface of Texas, and at numerous places in the

Bethany Falls of Iowa, Missouri, and Kansas.

The Confederate limestone in the Ardmore Basin of southern Oklahoma contains a very prolific fauna of a fusulinid which resembles somewhat closely *Wedekindellina ultimata*. The Oklahoma species differs from typical *W. ultimata* by its much thinner axial filling, somewhat more inflated shell, and larger shell. That the differences observed between *W. ultimata* and the Oklahoma form constitute specific differences rather than a subspecific difference may be questioned. It is realized that these differences observed may be due to differences in environment comparable to nearby but isolated environments which have resulted in the development of subspecies among modern faunas of vertebrates. However, from a paleontologic point of view, we consider these differences of sufficient magnitude for specific separation, and we are describing the Oklahoma form below as the new species *Wedekindellina ardmorensis*.

Wedekindellina is abundant in many lower and middle Desmoinesian rocks where other fusulinids are scarce or may be absent. Also, many Cherokee rocks contain prolific faunas of *Fusulina* and few, if any, specimens of *Wedekindellina*. So far as known, *Wedekindellina* is not present in the Marmaton group of the upper Desmoinesian, in spite of the fact that the upper Cherokee group immediately below the Marmaton has very abundant *Wedekindellina*. Again, in the Bethany Falls limestone and equivalent rock of the lower Missourian, *W. ultimata* appears in great abundance and just as suddenly disappears from the section. The geographic migrations of *Wedekindellina* during these times and later have not been determined.

EARLY *Triticites*

The lowest *Triticites* in the Missourian of Iowa, Missouri, and Kansas is represented by the abundant species in the Winterset limestone, *T. ohioensis* Thompson, except for the scarce fragmentary specimens of *Triticites* reported by Newell & Keroher (1937) in association with *Wedekindellina ultimata* in the Bethany Falls limestone of Kansas and Missouri. This occurrence has not been confirmed. The shell of *T. ohioensis* is large and highly elongate fusiform in shape, with a spirotheca that has a typical and well-developed keriothecal structure. This species does not seem to be an extremely primitive form of the genus and is not considered to be one of the earliest species of the genus. The new form from the Winterset limestone that we are describing as *T. winterensis* has many features which indicate advancement.

Forms of *Triticites* are found in lowermost Canyon rocks of Texas which are smaller, have thinner spirotheca, and seem more primitive than *T. ohioensis*. It should be pointed out, however, that the ancestral stock of *Triticites* is not known with certainty, and the shell features to be expected in the "first" *Triticites* can not be predicted exactly. It is reasonably certain that *Triticites* was not derived from a fusulinid similar to any of the *Fusulina* so abundant in the Desmoinesian.

THE GENUS *Oketaella*

The genus *Oketaella* was described by Thompson in 1952 with *O. fryei* Thompson from the Oketo shale of the Wolfcampian of Kansas as the genotype. The genus has since been observed at many horizons in the Wolfcampian and in the Pennsylvanian. Species of the genus are minute in size and have shell features which are not complex. The stratigraphic range of the genus has not been established and individual species have not been recognized as good index fossils. Furthermore, evolutionary trends have not been determined among species of the genus.

Thompson (1942) reported a fusulinid in the lower part of the type section of the Coane formation of New Mexico as *Triticites* (?). The minute fusulinid has almost unfluted septa and an inflated fusiform shape. It is described below as *Oketaella oscurensis*, n. sp. and is somewhat similar to the minute fusulinid in the type section of the Lenapah limestone of Oklahoma described below as *O. lenensis*, n. sp. The stratigraphic ranges of these species of *Oketaella* have not been determined, and it can not be concluded at this time how closely similar in age the lower part of the Coane is to the Lenapah. If the lower part of the Coane is the correlative of the Lena-

pah, according to the generally accepted classification of the Lenapah of Oklahoma, the basal part of the Coane is to be referred to the Desmoinesian. However, we prefer to continue to refer all of the Coane formation to the Missourian, unless later information proves it to be otherwise.

FAUNAL SUMMARY

The fusulinid fauna of the upper Desmoinesian is composed largely of advanced species of *Fusulina*. However, according to the present limitations assigned to the series of Iowa, fusulinids have not been found in its uppermost beds. The upper Desmoinesian Lenapah limestone of Oklahoma and Kansas contains a species of *Oketaella*.

The lower part of the Missourian of Iowa contains no known fusulinid, and the lower Coane limestones of New Mexico contain a minute fusulinid here referred to the genus *Oketaella*.

The Bethany Falls limestone of the northern midcontinent contains a large fauna of *Wedekindellina ultimata*, less abundant specimens of an advanced species of *Fusulina*, and possibly specimens of *Triticites*. At least in the subsurface of Texas, *Wedekindellina ultimata* may range up into rocks with a typical *Triticites* fauna.

The first *Triticites* fauna in the Missourian of Iowa, Kansas, and Missouri is from the Winterset limestone where abundant *T. ohioensis* Thompson is associated with the new species described below as *T. winterensis*.

The accompanying diagrammatic illustration across the Desmoinesian-Missourian contact (Text-fig. 1) has typical specimens of *Fusulina megista* Thompson from the Worland limestone of Iowa and Kansas and *F. eximia* Thompson from the Cooper Creek limestone of Iowa ("Floating rock"), *Oketaella lenensis*, n. sp., from the Lenapah limestone of Oklahoma, *O. oscurensis*, n. sp., from the Coane formation of New Mexico, *Wedekindellina ultimata* Newell & Keroher from the Bethany Falls limestone of Iowa, Missouri, and Kansas, and the Coane formation of New Mexico, *Fusulina fallsensis*, n. sp., from the Bethany Falls limestone of Kansas and Missouri, *Triticites ohioensis* Thompson and *T. winterensis*, n. sp., from the Winterset limestone of Iowa; and several species of *Triticites* from lower Missourian limestones above the Coane formation at several places in New Mexico.

COLLECTION LOCALITIES

Iowa

I-2 & I-48. Bethany Falls limestone; west half sec. 6, T. 75 N., R. 37 W., Madison County, Iowa just west of U. S. Highway 169.

I-16. Cooper Creek limestone ("Floating rock"); in the west part of SE ¼, sec. 26, T. 69 N., R. 18 W., Appanoose County, Iowa.

I-22. Worland limestone ("Fifty-foot limestone"); one and a half miles west of Sunshine, Iowa on the south side of Iowa Highway 3, NW ¼, NE ¼, sec. 32, T. 69 N., R. 18 W., Appanoose County, Iowa.

I-44. Winterset limestone; near the middle of the limestone, in old quarry on the south edge of Winterset, Madison County, Iowa in the west half sec. 6, T. 75 N., R. 37 W.

I-53. Winterset limestone; lower part of limestone, same locality as I-44.

Kansas

K-77. Worland limestone member of Altamont limestone; exposed in a barnyard on the north side of east-west road, SE¼, sec. 24, T. 25 S., R. 22 E., Bourbon County, Kansas.

K-363-52. Bethany Falls limestone; in the railroad cut near the center of the south edge, NW ¼, sec. 12, T. 19 S., R. 23 E., Miami County, Kansas

Missouri

M-3. Bethany Falls limestone; SE ¼, SW ¼, sec. 17, T. 49 N., R. 32 W., Jackson County, Missouri.

M-2-52. Bethany Falls limestone; about three miles northeast of Martin City, NE ¼, sec. 33, T. 48 N., R. 33 W., Jackson County, Missouri.

Oklahoma

O-68. Confederate limestone; center of the north line, NE ¼, NW ¼, sec. 17, T. 5 S., R. 2 E., south of Ardmore, Oklahoma.

O-78. Lenapah limestone; just west of highway at Lenapah, Oklahoma, NW ¼,

NE ¼, sec. 30, T. 28 N., R. 16 E., Nowata County, Oklahoma.
O-101. Confederate limestone; in the north center, SE ¼, sec. 17, T. 5 S., R. 2 E., 2.5 miles south of Ardmore, Oklahoma.

New Mexico

Section 5. Measured on the west front of the Oscura Mountains, Socorro County, New Mexico, SE ¼, sec. 36, T. 5 S., R. 6 E.
Section 24. Measured on the east front of the second to northernmost spur northwest of Ladron Mountain, SW ¼, sec. 3, T. 3 S., R. 3 W., Socorro County, New Mexico.
Section 31. Measured on the west face of the cliff 8.4 miles east of Bernalillo, New Mexico, on the northeast side of Sandia Mountains.

SYSTEMATIC PALEONTOLOGY

Oketaella lenensis T., V. & L., n. sp.

Pl. 89, fig. 1–5

The shell of *Oketaella lenensis* is minute in size and short and inflated subfusiform in shape; with a straight axis of coiling, convex to slightly concave lateral surfaces, and acutely pointed polar ends. Shells of three to four and a half volutions are about 1.29 to 1.67 mm long and 0.44 to 0.73 mm wide, giving form ratios of 1.9 to 2.3. The first volution is about spherical in shape and the axis of coiling uniformly increases in length to the mature subfusiform shape. Averages of the form ratios of the first to the fourth volution of two specimens are 1.1, 1.3, 1.6, and 2.1, respectively.

The proloculus is relatively very large and spherical in shape and has an outside diameter of 66 to 124 microns, averaging 101 microns for four specimens. The chambers are lowest above the tunnel, and they increase in height slowly to the polar areas. Averages of the heights of the chambers above the tunnel in the first to the fourth volution of four specimens are 40, 65, 90, and 98 microns, respectively.

The spirotheca is thin and is composed of the tectum and a thicker clear lower layer which shows a porous structure. It can not be determined from our specimens if the spirotheca has an alveolar keriotheca. Averages of the thicknesses of the spirotheca in the third and fourth volutions of two specimens are 19 and 21 microns, respectively. The proloculus wall is too thin for accurate measurement.

The septa are closely spaced and the chambers increase in length about uniformly throughout all volutions. The septal counts of the first to the third volution of two specimens average about 11, 15, and 22, respectively. The septa are plane across the central third of the shell and are broadly fluted in their polar areas. The fluting extends almost to the tops of the chambers in the end quarters.

The tunnel is very narrow, and its path is irregular. The tunnel angle of the holotype measures about 23 degrees in the third volution and 21 degrees in the fourth volution. The chomata are about half as high as the chambers and they have steep tunnel sides and low lateral slopes. In fact, the chomata extend at least two-thirds the distance from the tunnel to the poles. Thickening on the tops of the spirotheca in the polar areas may be lateral extensions of chomata deposits.

Remarks.—*Oketaella lenensis* belongs to a minute group of fusulinids that are common from Middle Pennsylvanian to at least the middle part of the Wolfcampian. They have not been recognized in all parts of this section, for most commonly the larger species are in abundance and the minute faunas may be overlooked. These smaller fusulinids have short and inflated fusiform shells like the juvenile shells of larger fusulinids and could be recognized only from thin sections. It is evident that the great numbers of juvenile specimens of large fusulinids in association with possible minute mature but less abundant *Oketaella* are not exhaustively sectioned in search of these smaller species. As a result, species of this minute type are most commonly observed where other fusulinids are absent or are scarce. Examples of this type are found in the Oketo shale of Kansas, the Camp Colorado shale and Ibex limestone of Texas, the lower Coane limestone of New Mexico, and the Lenapah limestone of Oklahoma.

Oketaella lenensis resembles in some respects *O. oscurensis*, but can be distinguished from that species by its larger and more elongate shell and less uniformly convex lateral surfaces.

Occurrence.—Oketaella lenensis is rather scarce in the Perry Farm shale of the Lenapah limestone at Lenapah, Oklahoma (0-78).

OKETAELLA OSCURENSIS T., V. & L., n. sp.
Pl. 89, fig. 6–11

Triticites? sp. THOMPSON, 1942, New Mexico Bureau Mines, Bull. 17, p. 60.

The shell of *Oketaella oscurensis* is minute in size and inflated ellipsoidal in shape; with broadly rounded lateral surfaces, bluntly rounded to broadly rounded polar ends, and a straight axis of coiling. Our largest shell, the holotype, of three and a half volutions is about 0.67 mm long and 0.57 mm wide, giving a form ratio of about 1.2. A paratype specimen of four volutions is 0.67 mm long and 0.48 mm wide, giving a form ratio of about 1.4. The first volution is about spherical in shape, the following two volutions are almost spherical in shape, and the axis of outer volutions becomes slightly extended. Average form ratios of the first to the fourth volution of three specimens are about 0.86, 1.09, 1.31, and 1.40, respectively.

The proloculus is spherical in shape and has an outside diameter of 75 to 120 microns, averaging 93 microns for four specimens. Average heights of the chambers above the tunnel in the first to fourth volution are about 32, 52, 83, and 89 microns, respectively. The chambers increase in height only slightly as the polar ends are approached.

The spirotheca is thin and is composed of the tectum and a lower layer showing suggestions of alveoli. It measures 9, 12, and 16 microns in the second to the fourth volution, respectively. The proloculus wall is too thin to measure accurately.

The septa are plane in the central part of the shell and are slightly irregular in the polar ends. A typical paratype has 10, 13, and 14 septa in the first to the third volution, respectively, and another has 8, 12, and 14 septa in the same volutions.

The tunnel is very narrow, and its cross section is highly ellipsoidal in shape. It is slightly more than half as high as the chambers, and its path is somewhat sinuous. The tunnel angle measures only about 20 and 27 to 33 degrees in the third and fourth volutions. The chomata are large and are highly asymmetrical, with steep tunnel sides and lower lateral surfaces. In the third volution the chomata are about two-thirds as high as the chambers.

Remarks.—Oketaella oscurensis can be distinguished from other species of the genus by its inflated ellipsoidal shape and broadly convex lateral surfaces. Comparisons with *O. lenensis* are given above.

Thompson (1942) listed this form as *Triticites* (?). It resembles *Triticites* in many respects and may possibly be of the general type of fusulinid from which *Triticites* was derived. It differs from *Triticites* by its minute size and the lack of a distinctly alveolar kerotheca.

Occurrence.—Oketaella oscurensis is scarce in the lower part of the type section of the Coane formation of New Mexico (Bed 1-G, Section 5).

FUSULINA FALLSENSIS T., V. & L., n. sp.
Pl. 89, fig. 12–23

The shell of *Fusulina fallsensis* is highly irregularly fusiform to subcylindrical in shape; with rounded to irregular polar ends, shifting to irregular axis of coiling, and irregular to convex lateral slopes. Larger shells contain four to five volutions and have an average form ratio of 2.4 for nine specimens. The holotype specimen of five volutions measures about 2.9 mm long and 1.6 mm wide giving a form ratio of about 1.8. Another typical specimen of five volutions measures 3.5 mm long and 1.6 mm wide, giving a form ratio of 2.2. The averages of the form ratios of the first to the fifth volution of eight specimens are 1.3, 1.7, 2.0, 2.2, and 2.0, respectively. These average determinations of the form ratios have little significance, however, for no single specimen has ratios that correspond exactly with them. The shape of the shell of any given volution varies widely. For instance, the third volution of some specimens is elongate fusiform with sharply pointed polar ends, but the same volution of other specimens is inflated irregularly and is ellipsoidal in shape with broadly rounded polar ends.

The proloculus is abnormally large for the size of the shell, and it is highly irregular in shape. In some specimens it is spherical in shape but in most specimens it

is deeply depressed around the proloculus pore and very broadly convex on the opposite side. Its greatest diameter varies from 219 to 353 microns, averaging 257 microns for thirteen specimens. In general, the chambers are lowest immediately above the tunnel, but many of them are variable in height from pole to pole. The lateral surfaces turn into the polar ends rather sharply in outer volutions, resulting in blunt to rounded polar ends.

The spirotheca is thin and is composed of the tectum and the diaphanotheca, the latter of which shows a porous structure in some parts of the shell. Upper and lower tectoria seem discontinuous in various parts of the shell. The thicknesses of the tectum and diaphanotheca in the third and fourth volutions of the holotype specimen measure about 24 and 27 microns, respectively. The proloculus wall of this same specimen measures about 15 microns. Averages of the thicknesses of the spirotheca in the first to the fifth volution of twelve specimens, including the holotype, are 14, 18, 22, and 24 microns, respectively.

The septa are thin and are fluted throughout the length of the shell so as to form closed chamberlets above the tunnel. Closed chamberlets extend about three-fourths as high as the chambers immediately adjacent to the tunnel. The fluting is not uniform laterally along the septa or vertically up the septa. Averages of the septal counts of the first to the fourth volution of three specimens are 10, 19, 25 and 30, respectively.

The tunnel is narrow and its path is irregular. The irregular path of the tunnel corresponds to the irregularly shifting axis of coiling. In one specimen, the tunnel path in the first volution is almost parallel to the axes of outer volutions. Also, the width of the tunnel varies considerably for a given volution among different specimens. Although the tunnel angle is quite variable among different specimens, it averages about 28, 30, and 50 degrees in the third to the fifth volution, respectively, of eight specimens. Chomata deposits are heavy but are irregularly spread along the septa and spirotheca. Most volutions contain slightly asymmetrical chomata which are about a

Measurements of *Fusulina fallsensis*, n. sp., in millimeters

Specimen	L.	W.	Ratio	Diam. of Prol.	Height of volutions					Form ratio of volutions				
					1	2	3	4	5	1	2	3	4	5
1	3.1	1.2	2.6	.353/.270	.080	.106	.139	.162	—	1.1	1.8	2.3	2.6	—
2	3.7	1.0	3.7	.264/.205	.063	.072	.094	.132	—	1.6	1.9	2.2	2.2	—
3	2.1	1.0	2.1	.313/.202	.091	.117	.127	—	—	1.5	1.8	2.0	—	—
4	3.0	1.4	2.1	.219	.066	.079	.129	.162	.183	1.2	1.5	2.0	2.0	2.1
5	—	1.2	—	.235	.062	.070	.127	.158	—	—	—	—	—	—
6	—	1.1	—	.293/.178	.092	.125	.177	—	—	—	—	—	—	—
7	—	1.3	—	.257	.084	.106	.131	.192	—	—	—	—	—	—
10	3.5	1.6	2.2	.325/.265	.070	.108	.125	.167	—	1.5	1.6	1.7	2.1	2.2
11	2.9	1.6	1.8	.288/.216	.090	.118	.143	.163	.217	—	—	—	—	1.8

Specimen	Thickness of spirotheca					Septal count					Tunnel angle (degrees)				
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
1	.016	.022	.024	—	—	—	—	—	—	—	—	—	—	—	—
2	—	.019	.024	—	—	—	—	—	—	—	—	—	30	29	—
3	—	.016	.022	—	—	—	—	—	—	—	—	—	27	—	—
4	.015	.019	.025	.029	—	—	—	—	—	—	—	—	28	31	50
5	.012	.014	.018	—	—	10	19	25	30	—	—	—	—	—	—
6	—	.023	—	—	—	10	20	29	—	—	—	—	—	—	—
7	—	.013	.019	—	—	9	18	22	29	—	—	—	—	—	—
10	—	.018	.023	.019	—	—	—	—	—	—	—	—	28	30	—
11	—	—	.024	.027	—	—	—	—	—	—	—	—	—	23	—

third as high as the chambers. Axial fillings completely fill chambers in the first two to three volutions in some specimens and only partly fill the chambers in extreme polar ends of outer volutions.

Remarks.—*Fusulina fallsensis* has one of the most highly irregularly shaped shells of any known species of the genus. The shell shape varies from an almost perfectly fusiform shape to a highly crooked shape. Also, its general shell volume varies considerably among different specimens. It can be distinguished from other species of the genus by its irregular shape, the loose and irregular coiling of its shell, its large and irregular proloculus, its discontinuous tectoria, its axial fillings, and its irregularly fluted septa. The general spirothecal structure of *Fusulina fallsensis* compares closely with that of *F. eximia* from the Cooper Creek limestone of Iowa and of *F. cylindrica* of the upper Moscovian of Russia. Both of these species are highly elongate subcylindrical in shape and are considerably larger in size than *F. fallsensis*. The proloculus of *F. eximia* is about spherical in shape and is minute in size. In contrast, the proloculus of *F. fallsensis* is very large and is highly irregular in shape. *F. cylindrica* also has a large irregular proloculus. The early volutions of *F. eximia* are symmetrical with the outer volutions, but in contrast the early volutions of both *F. fallsensis* and *F. cylindrica* are variable in their general attitude toward outer volutions.

Fusulina cylindrica has irregularly distributed axial fillings somewhat like that in *F. fallsensis* but the fillings of the former are somewhat heavier. Also, *F. eximia* has very slight and discontinuous axial fillings. It is generally agreed that species like *F. cylindrica* are on one extreme end of the genus *Fusulina* and such lower Desmoinesian species like *F. prima* are on the other extreme near the earliest species of the genus. The great numbers of species of the genus between rocks of lower Desmoinesian age and late Moscovian (probably early Missourian) are in a large part quite different from *F. cylindrica*, except that they have septal fluting throughout the length of their shells and a spirothecal structure somewhat alike. The genotype of *Quasifusulina*, *Fusulina longissima* Möller, actually has many more shell features similar to those of *F. cylindrica* than do the lower Desmoinesian species.

Due largely to a misinterpretation of shell features, Möller (1877) established the genus *Hemifusulina* in 1877. *H. bocki* Möller (*Fusulina minima* Schellwien, 1908), the genotype, was not described until the folllowing year. The type species of *Hemifusulina* is very closely similar to the lower Desmoinesian fusulinids now generally referred to *Fusulina*. Also, Galloway (1933) established the genus *Beedina* (with *Fusulinella girtyi* Dunbar & Condra as the genotype) for the Desmoinesian type of fusulinid now referred to *Fusulina*.

If the lower Desmoinesian fusulinids now commonly referred to *Fusulina* are to be separated generically from *F. cylindrica*, *Hemifusulina* is the earliest valid genus established for them and it has priority over the name *Beedina* proposed by Galloway. Both *Hemifusulina* and *Beedina* are here suppressed as synonyms of *Fusulina*. However, should either or both be resurrected for the Desmoinesian species, the species here described as *F. fallsensis* would surely be left in the genus *Fusulina*. In other words, *F. fallsensis* is a typical form of the genus.

Occurrence.—*Fusulina fallsensis* is rather scarce in association with abundant *Wedekindellina ultimata* in the Bethany Falls limestone within the neighborhood of Kansas City, Missouri and Kansas City, Kansas. The above description is based on specimens from the Bethany Falls in Miami County, Kansas (K-363-52) and Jackson County, Missouri (M-2-52).

WEDEKINDELLINA ULTIMATA Newell & Keroher

Pl. 90, fig. 1–11; Pl. 91, fig. 1–15

Wedekindellina ultimata NEWELL & KEROHER, 1937, Jour. Paleont, vol. 11, p. 700–705, pl. 93, fig. 1–9.

The shell of *Wedekindellina ultimata* is highly elongate fusiform in shape; with sharply to bluntly pointed polar ends, straight to curving or irregular axis of coiling, inflated central area, and slightly concave to almost straight but low lateral slopes. Larger shells of seven to eight volu-

tions measure 4.4 to 6.2 mm long and 1.2 to 1.5 mm wide, giving form ratios of 3.1 to 4.4. As these figures and the accompanying data indicate, shells of the same number of volutions are not of uniform size. The first volution is almost round but the axes become rapidly extended and the form ratios increase rapidly to the fourth or fifth volution. Averages of the form ratios of the first to the eighth volution of seven specimens are 1.4, 1.9, 2.3, 2.9, 3.0, 3.2, 3.4, and 3.7, respectively. Many larger specimens develop curved or irregular axes in the polar region, and thin sections along the axial line are not obtained in all specimens.

The proloculus is small and spherical in most specimens, measuring 75 to 127 microns in outside diameter and averaging 104 microns in nine specimens. Averages of the heights of the chambers above the tunnel in ten specimens are 36, 40, 56, 67, 86, 106, 121, and 140 microns, respectively. The chambers are lowest above the tunnel, and they increase in height slowly poleward and become highest near the polar ends.

The spirotheca is thin throughout the shell but is thickest above the tunnel. It is composed of the tectum and diaphanotheca and is covered above and below by rather thick layers of tectoria. The thick and broad chomata and heavy axial filling which join the chomata in most volutions are difficult to distinguish from the tectoria. The proloculus wall is too thin to measure accurately. Averages of the combined thicknesses of the tectum and diaphanotheca in the fourth to seventh volution of nine specimens are 13, 15, 16, and 19 microns, respectively.

The septa are closely spaced throughout the shell. They are plane across the central half of the shell and are fluted in the end quarters. However, the fluting forms closed chamberlets only in the extreme end zone. Averages of the septal counts of the first to the seventh volution of three specimens are 10, 17, 20, 22, 22, 24, and 28, respectively.

The tunnel is slightly more than half as high as the chambers and is moderately narrow. It expands in width very slowly to the fifth or sixth volution and has a path that is almost straight. Averages of the tunnel angle in fourth to the eighth volution are 19, 23, 27, 33, and 27 degrees, respectively. The chomata are high and broad and have vertical to overhanging tunnel sides and low poleward slopes. In inner volutions they join with the axial filling without an obvious break, but in outer volutions of most specimens they are broad but separated from the axial fillings. In an occasional specimen the axial fillings are continuous with the chomata even to the ultimate volution. Axial fillings are very heavy in typical specimens and completely fill most of the chambers in the axial areas of all volutions except the outer one to three volutions. They do not seem of exactly the same weight in all specimens even from the same locality but are invariably rather heavy at all places studied in Kansas, Missouri, and Iowa.

Remarks.—The above description is based on topotype specimens of *Wedekindellina*

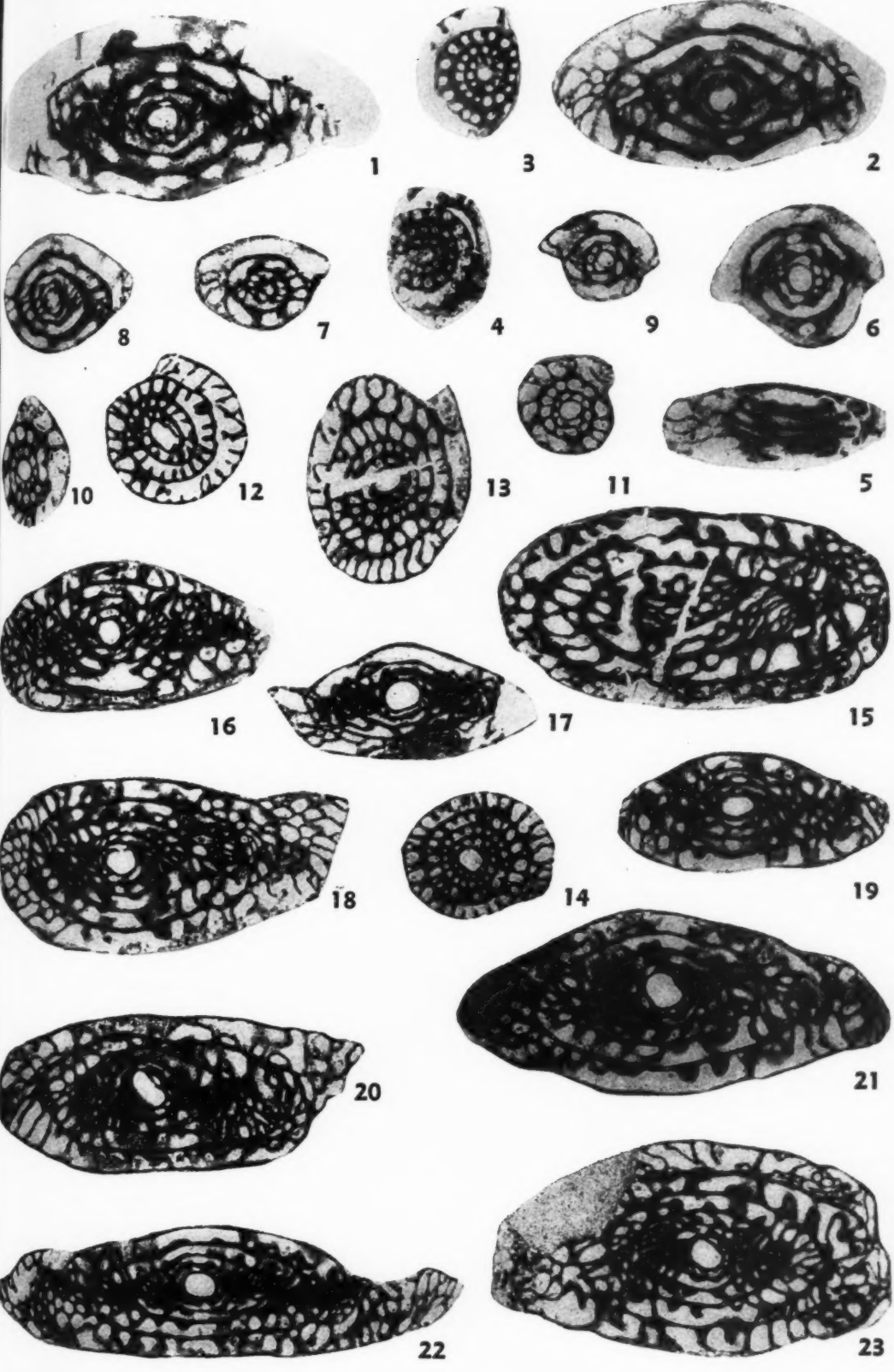
EXPLANATION OF PLATE 89

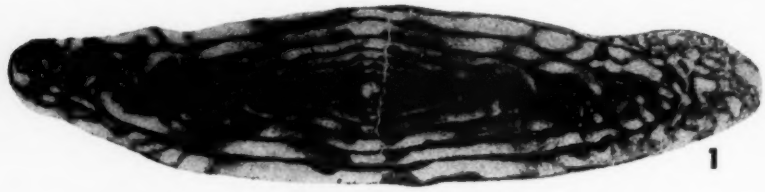
All illustrations on this plate are unretouched photographs. *1–11* are magnified ×40 and *12–23* are magnified ×20.

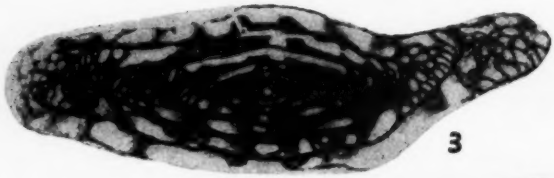
FIG. *1–5—Oketaella lenensis*, n. sp. *1*, Axial section of a paratype; *2*, axial section of the holotype; *3,4*, sagittal sections of paratypes; and *5*, tangential section of a paratype. All from the type section of the Lenapah limestone of Oklahoma (0–78). *1* to *4* are of specimens 2, 1, 3, and 4, respectively.

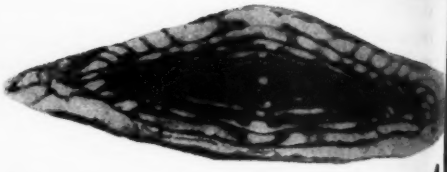
6–11—Oketaella oscurensis, n. sp. *6*, Axial section of the holotype; *7–9*, axial sections of paratypes; and *10,11*, sagittal sections of paratypes. All from the Coane formation of New Mexico (Bed 1-G, Section 5). *6,8*, and *10* are of specimens 1, 3, and 4, respectively.

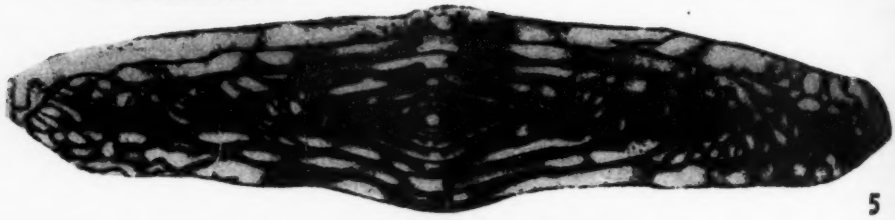
12–23—Fusulina fallsensis, n. sp. *12–14*, Sagittal sections of paratypes; *15*, tangential section of a paratype showing fluting; *16–22*, axial sections of paratypes, and *23*, axial section of the holotype. Bethany Falls limestone: *12–14,16,18–20*, and *22* are from Missouri (2-52); and *15,17,21*, and *23* are from Kansas (363-52). *12–14* and *16–23* are of specimens 6, 7, 5, 8, 9, 4, 3, 1, 10, 2, and 11, respectively.

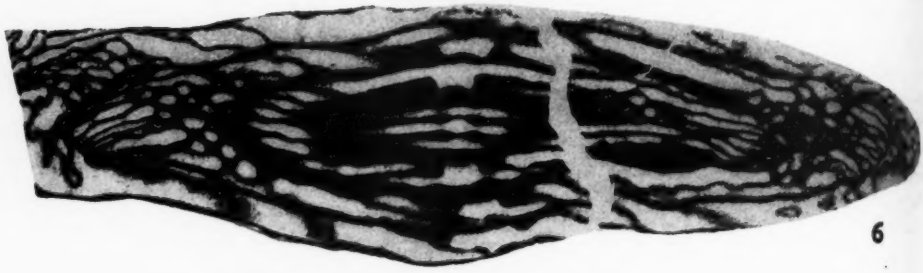

1
3
2
8
7
4
9
6
10
12
13
11
5
16
17
15
18
14
19
20
21
22
23

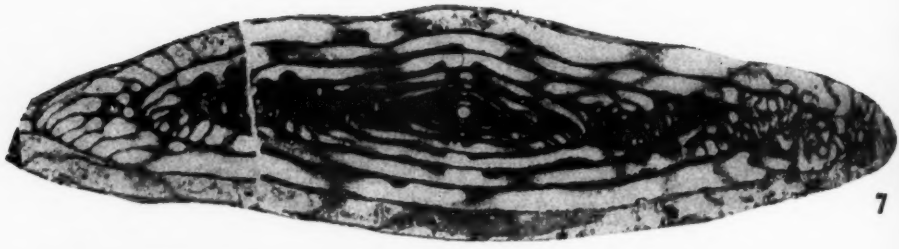

1

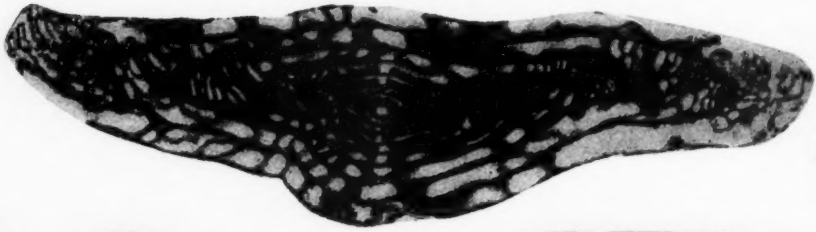

3

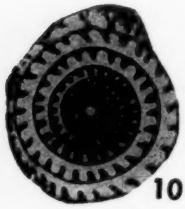

4

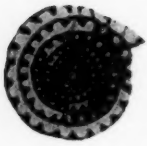

5

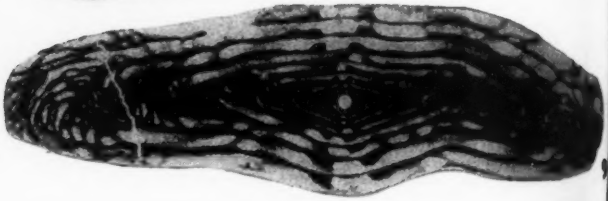

6


7


8


10


11



ultimata from the Bethany Falls limestone in Jackson County, Missouri, and in Miami County, Kansas, both in the greater Kansas City area, and from the Bethany Falls near Winterset, Iowa. The specimens from the vicinity of Kansas City seem somewhat larger than those from Iowa but this may be more apparent than real. In general, the axial fillings in both localities are closely similar, and most of our axial sections from Iowa contain one less volution.

Specimens here referred to this species are very abundant in the Coane formation at many places in New Mexico and is one of the better key index fossils for this part of the stratigraphic section. In fact, it composes large percentages of the upper Coane limestone over wide areas. Numerous thin sections have been prepared of the New Mexico collection and many of them have been measured. In general, the New Mexico specimens are smaller than the types from Missouri and they may represent different subspecies. However, close comparisons of large numbers of specimens from both localities lead us to conclude that separation is not advisable at this time. We are illustrating numerous New Mexico specimens for comparative purposes and are including measurements of some.

Wedekindellina ultimata differs from *W. ardmorensis*, n. sp., particularly by its more tightly coiled outer volutions, more closely spaced outer septa, more dense axial fillings, and heavier chomata.

The group of specimens here described as *Wedekindellina ultimata* and *W. ardmorensis* all have axial fillings as in typical *Wedekindellina*, have wall structures as in the genotype species, have closely spaced septa as in the genotype, and have elongate very slender shells with inflated central areas as in the genotype and most other lower Desmoinesian typical species. They differ from the genotype particularly in their septal fluting developed in the polar regions. In this latter respect they resemble *Pseudofusulinella occidentalis* (Thompson & Wheeler), the genotype of *Pseudofusulinella*. However the wall structure of the latter species seem different from the lower Missourian species.

Wedekindellina ultimata is very abundant over wide areas in central United States west of the Mississippi River to the New Mexico region. It seems restricted to the same general part of the stratigraphic section above the base of the Missourian and constitutes one of the very best of the index fossils for correlation of lower Missourian rocks.

Occurrence.—*Wedekindellina ultimata* Newell & Keroher has been observed at many places in the Bethany Falls limestone in Iowa (I-2, I-48), Missouri (M-3, M-4, M-8, M-39, M-2-52), and Kansas (K-33, K-363-52). At the locality M-2-52 and M-363-52 this species is associated with common specimens of *Fusulina fallsensis*, n. sp. Abundant specimens are also found in subsurface lower Missourian rocks of Texas and in the Coane formation exposed in many parts of New Mexico. It is restricted to the Coane formation in New Mexico where it is exceedingly abundant in the Oscura Mountains (Beds 1-H and 2, Section 5); Ladron Mountain area (Beds 19 and 23, Section 24); and Sandia Mountains (Beds 111 and 115, Section 31).

WEDEKINDELLINA ARDMORENSIS
T., V. & L., n. sp.
Pl. 92, fig. 1–12

The shell of *Wedekindellina ardmorensis*, n. sp., is elongated fusiform in shape and has sharply pointed polar ends, moderately low

---

EXPLANATION OF PLATE 90

All illustrations on this plate are unretouched photographs, and are magnified ×20.

FIG. *1–11*—*Wedekindellina ultimata* Newell & Keroher. *1,9*, Axial sections of topotypes; *2,11*, sagittal sections of topotypes; *3–5,7,8*, axial sections; *6*, tangential section showing septal fluting; *10*, sagittal section, *1,2,9*, and 11 are of specimens 1, 5, 4, and 6 from the Bethany Falls at Kansas City (M-3); *3,4*, and *10* from the Bethany Falls limestone at Winterset, Iowa (I-2, I-48); *5* and *8* are of specimens 10 and 9 from the Bethany Falls at Kansas City, Missouri (2-52); and *7* (specimen 8) and *6* are from the same limestone at Kansas City, Kansas (363-52).

Measurements of *Wedekindellina ultimata* Newell & Keroher, in millimeters

Specimen	L.	W.	Ratio	Diam. of prol.	Height of volutions								Form ratio of volutions							
					1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
1	5.0	1.2	4.2	.127	.044	.045	.056	.059	.085	.120	.104	—	1.3	1.8	2.5	2.8	3.1	3.1	3.5	—
4	4.4	1.3	3.4	.106	.028	.038	.050	.063	.094	.106	.106	.165	1.4	1.9	2.4	3.1	3.2	3.4	3.4	—
5	—	—	—	.075	.035	.026	.038	.068	.066	.075	.096	.124	—	—	—	—	—	—	—	—
6	—	0.9	—	.085	.037	.031	.040	.059	.080	.097	.103	—	—	—	—	—	—	—	—	—
8	5.9	1.5	3.9	.102	.033	.039	.064	.084	.102	.141	.162	—	1.0	1.0	1.3	1.5	1.6	1.9	3.9	3.9
9	5.3	1.5	3.5	.107	.047	.051	.073	.065	.087	.108	.140	.155	2.5	2.0	2.4	2.5	2.4	2.8	3.8	3.5
10	6.2	1.4	4.4	.123	.039	.047	.059	.090	.109	.115	.135	—	1.6	2.7	3.1	4.4	4.0	4.2	4.4	—

Specimen	Thickness of spirotheca								Septal count								Tunnel angle (degrees)							
	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
1	—	—	.010	.014	.014	.014	—	—	—	—	—	—	—	—	—	—	—	—	17	22	29	30	39	—
4	—	—	.010	.012	.017	.016	—	—	—	—	—	—	—	—	—	—	—	—	19	17	19	23	27	26
5	—	—	—	—	.016	.012	—	.024	10	16	17	20	21	25	27	—	—	—	—	—	—	—	—	—
6	—	—	—	—	—	—	—	—	9	17	18	20	22	23	—	—	—	—	—	—	—	—	—	—
8	—	—	—	.012	.013	.023	.022	—	—	—	—	—	—	—	—	—	—	—	—	21	28	34	39	—
9	—	—	—	—	.018	—	—	—	—	—	—	—	—	—	—	—	—	—	—	17	14	18	25	31
10	—	—	.008	.013	.016	.021	—	—	—	—	—	—	—	—	—	—	—	—	—	19	21	31	41	—

Measurements of *Wedekindellina ultimata* Newell & Keroher, in millimeters, from Coane formation of New Mexico (Bed 1-H, Section 5)

Specimen	L.	W.	Ratio	Diam. of prol.	Height of volutions							Form ratio of volutions						
					1	2	3	4	5	6	7	1	2	3	4	5	6	7
1	5.0	1.2	4.2	.073	.026	.044	.045	.054	.084	.110	.127	0.9	1.4	1.8	2.2	3.0	3.2	3.3
2	4.0	1.1	3.6	.113	.024	.056	.056	.075	.097	.103	.144	1.8	1.9	2.2	2.3	2.5	2.8	—
3	4.2	1.2	3.5	.077	.038	.040	.052	.070	.087	.124	.103	1.2	1.7	2.3	2.7	2.9	3.2	3.6
4	3.5	1.1	3.2	.085	.019	.038	.050	.066	.097	.117	.151	0.9	1.3	2.0	2.2	2.6	3.3	—
5	—	1.1	—	.073	.016	.044	.049	.063	.070	.120	.118	—	—	—	—	—	—	—
6	—	1.0	—	.101	.023	.033	.057	.068	.064	.111	.139	—	—	—	—	—	—	—

Specimen	Thickness of spirotheca							Septal count							Tunnel angle (degrees)							
	1	2	3	4	5	6	7	1	2	3	4	5	6	7	1	2	3	4	5	6	7	8
1	—	—	—	—	.009	.017	.019	—	—	—	—	—	—	—	—	—	19	21	23	30	31	46
2	—	—	—	.019	.028	.016	.019	—	—	—	—	—	—	—	—	—	—	15	22	25	39	—
3	—	—	—	.012	.010	—	—	—	—	—	—	—	—	—	—	—	17	20	25	26	24	—
4	—	—	—	.017	.017	.024	.019	—	—	—	—	—	—	—	—	—	—	18	25	30	—	—
5	—	—	—	.016	.012	.016	—	9	13	18	20	20	20	24	—	—	—	—	—	—	—	—
6	—	—	.009	—	.017	.019	.019	9	14	16	14	15	21	—	—	—	—	—	—	—	—	—

and convex to slightly irregular lateral slopes, and a straight to slightly shifting axis of coiling. The central area of the shell is inflated in most specimens and results in slightly concave lateral slopes on both sides of the center. Shells of seven to eight volutions are about 3.2 to 4.5 mm long and 1.2 to 1.7 mm wide, giving form ratios of 2.4 to 3.6. The first volution is about spherical in shape and beyond the first volution the polar ends become gradually extended and remain sharply pointed for the second volution to maturity. Averages of the form ratios of the first to the seventh volution of five specimens are 1.1, 1.6, 2.1, 2.3, 2.5, 2.8, and 2.9, respectively.

The proloculus is small and measures 70 to 89 microns in outside daimeter, averaging 80 microns in eight specimens. The shell expansion is uniform to the sixth volution and somewhat less so in outer volution. Average heights of the first to the seventh volution of seven specimens are 30, 41, 52, 72, 101, 144, and 157 microns, respectively. The chamber heights are relatively the same throughout the central parts of the shell but increase in height in the extreme polar regions of most outer volutions.

The wall structure is typical of the genus but has very thin tectoria. It increases in thickness very slowly and is too indistinct to measure accurately in the inner two volutions, and in the third volution of most specimens. Averages of the thickness of the tectum and diaphanotheca in the third to the seventh volution of seven specimens are 12, 14, 19, 20, and 26 microns, respectively. The proloculus wall is too indistinct to measure accurately.

The septa are closely spaced throughout the shell. They are plane in the central part of the shell but become irregularly fluted in the end zones. Closed chamberlets are confined to the extreme polar ends. Average septal counts of the first to the seventh volution of two specimens are 9, 12, 15, 18, 19, and 22, respectively. The septa are composed of an extension down its posterior side which seems continuous with the diaphanotheca and the tectum. The diaphanotheca of the spirotheca of the following chamber extends down the anterior side of the tectum for a short distance.

The tunnel is narrow and high and its path is only slightly irregular. The tunnel angle averages 23, 29, 35, and 39 degrees in the fourth to the seventh volution, respectively. The chomata are only about a third as high as the chambers and are very narrow. Their tunnel sides are about vertical and their poleward slopes are steep. Axial fillings are very light and are confined to the extreme polar ends.

Remarks.—The axial fillings of *Wedekindellina ardmorensis* are among the lightest of any form of the genus. Also, the chomata are among the smallest for any known form of the genus. In most forms of *Wedekindellina* the chomata extend laterally to join with the axial filling as heavy deposits, but in most specimens of this form the axial fillings and chomata do not join.

W. ardmorensis can be distinguished easily from other forms of the genus by the light axial fillings, small chomata, and more highly inflated outer chambers. It is possible that environmental conditions in the Ardmore Basin may have had some influence on the development of some of the features, but we have no evidence at the present time to support this possibility.

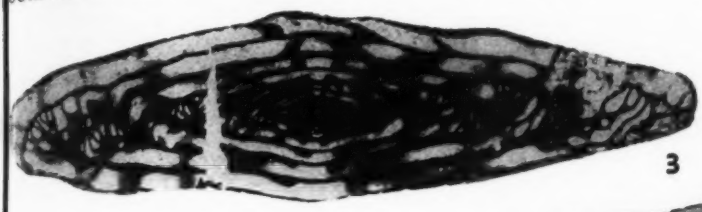
Occurrence.—*W. ardmorensis* is abundant in the Confederate limestone at many places in the Ardmore Basin of southern

---

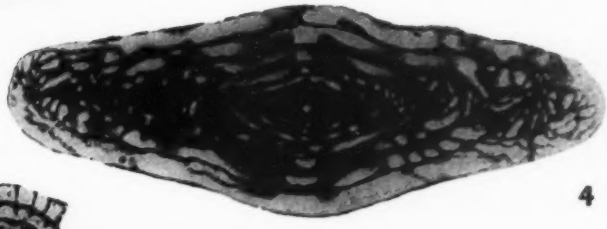
EXPLANATION OF PLATE 91

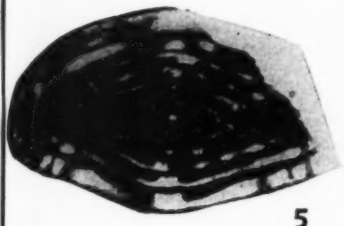
All illustrations on this plate are unretouched photographs, are magnified ×20, and are from the Coane formation of New Mexico.

FIG. *1–15*—*Wedekindellina ultimata* Newell & Keroher. *1,2*, Sagittal sections; *3–14*, axial sections; and *15*, tangential section. *1,2,3,6,7*, are of specimens 5, 6, 1, 2, and 3 from Bed 1-H, Section 5; *4,8*, and *14* are from Bed 23, Section 24; *5,11*, and *13* are from Bed 115, Section 31; *9* and *12* are from Bed 19, Section 24; and *10* is from Bed 111, Section 31; *15* is from Bed 1-H, Section 5.

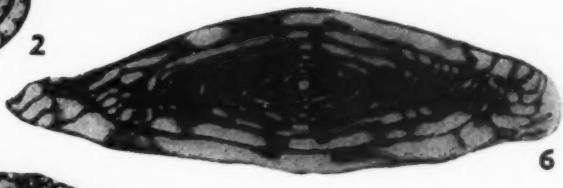

3

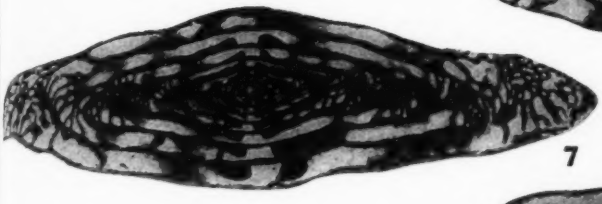
1

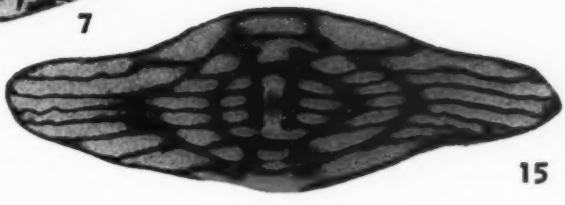

4

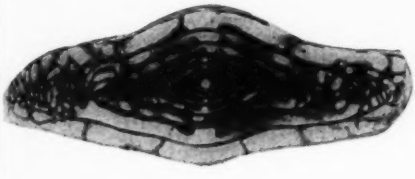

5

2

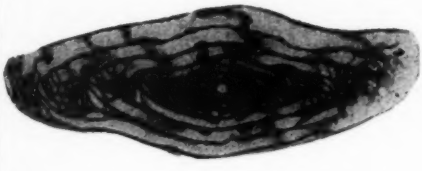

6


7

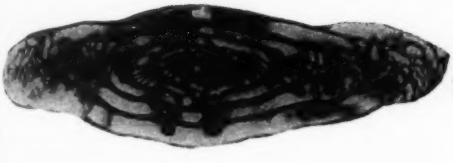

15

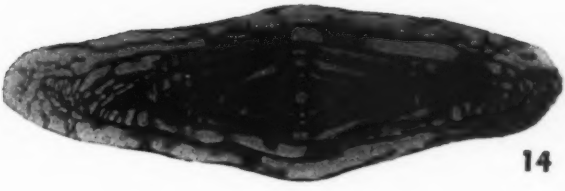

8

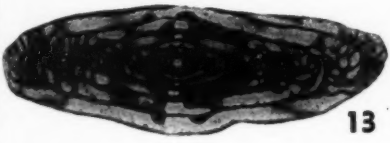
10


9

12

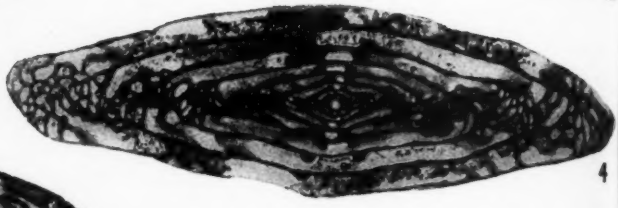

11

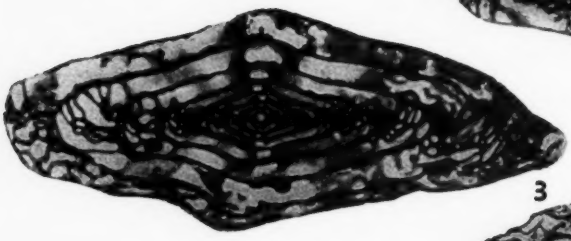

14


13

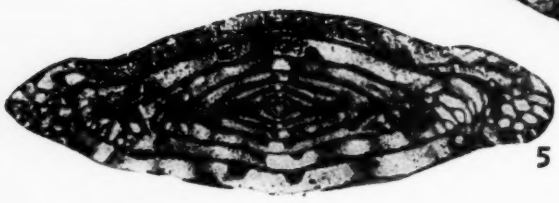
1

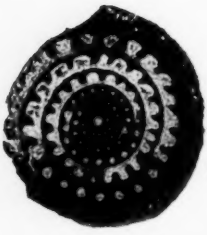
2

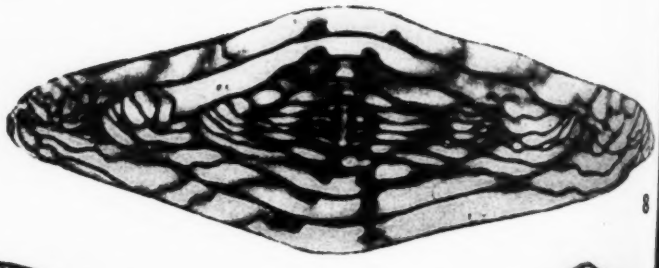

4

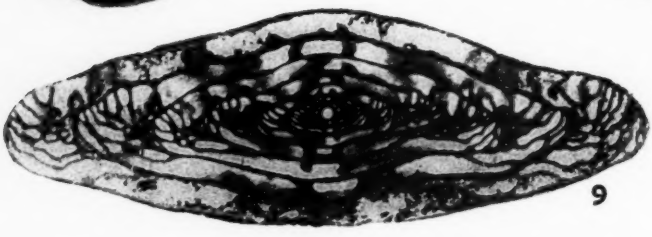

3

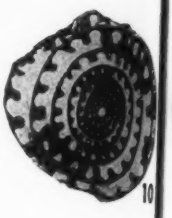
6


5

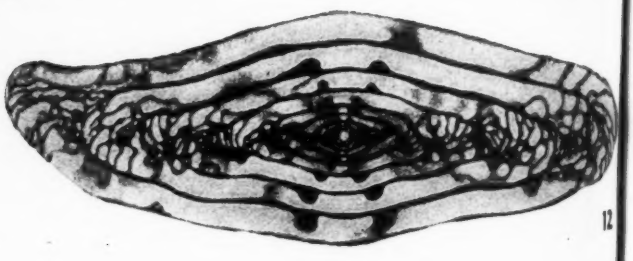

7


8


9


10

11


12

Oklahoma (0–68, 0–101) where it is not found in association with other fusulinids.

TRITICITES WINTERENSIS T., V. & L., n. sp.
Pl. 93, fig. 1–13

The shell of *Triticites winterensis*, n. sp., is moderately large in size and inflated fusiform in shape; with slightly inflated central area, bluntly rounded polar ends, slightly convex, almost straight, to slightly concave or irregular lateral slopes, and curving to slightly irregular axis of coiling. Mature specimens of seven to eight and a half volutions are 2.4 to 2.8 mm wide and 6.0 to 8.0 mm long, giving form ratios of 2.3 to 3.1. The first four to six volutions are ellipsoidal in profile, but beyond the sixth volution the polar ends are slightly more extended. Averages of the form ratios of the first to the seventh volution of six specimens are 1.4, 1.7, 1.8, 1.9, 2.1, 2.3, and 2.3, respectively.

The proloculus is small in size and spherical in shape. Its outside diameter measures 125 to 164 microns and averages 150 microns for seven specimens. The shell is tightly coiled, and the chambers increase in height about uniformly. Averages of the heights of the chambers in the first to the seventh volution of nine specimens are 41, 67, 91, 130, 185, 260, 303, and 330 microns, respectively. The chambers are of near the same height throughout their width in the inner six or seven volutions, but they increase in height rather sharply in the polar areas of the outer three to four volutions.

The spirotheca is thin in comparison to the size of the shell. It is coarsely alveolar in the outer volutions and shows distinct alveoli in the first volution of some specimens. However, in the first few volutions of some specimens it seems composed of the tectum and a lower structureless layer. Averages of the thicknesses of the spirotheca in the third to the eighth volution of nine specimens are 21, 25, 36, 49, 58, and 61 microns, respectively. The proloculus wall is thick and measures about 18 microns.

The septa are thin and are closely spaced. Averages of the septal counts of the first to the eighth volution of three specimens are 11, 19, 23, 28, 32, 36, 38, and 43, respectively. The septa are fluted throughout the length of the shell, and the fluting forms closed chamberlets even above the tunnel. However, the fluting seems irregularly spaced along the septa. The fluting in the outer volutions of larger specimens seems similar in nature to that found in the subgenus *Acervoschwagerina*.

The tunnel is narrow, and its path is straight to slightly irregular. The tunnel angle averages 17, 20, 23, 25, 32, and 26 degrees, respectively, in the third to the eighth volution. The chomata are high and broad and have almost flat upper surfaces, steep to overhanging tunnel sides, and steep poleward slopes. In the inner five to six volutions the chomata extend to the polar ends, and they extend almost to the poles in the outer volutions. They reach the tops of the chambers adjacent to the septa and only a minute circular lateral opening is left above the chomata near the center of the chambers. The chomata extend across the floor of the tunnel in most volutions and coat the ends of the septa near the tunnel to give them a pendant shape.

Remarks.—Triticites winterensis bears little resemblance to other fusulinids, such as *T. ohioensis*, found in lower Missourian rocks. It differs from the latter especially by its larger shell, its more highly fluted septa, and its much more massive and more spreading chomata. In fact, *T. winterensis* has the most massive chomata of any

EXPLANATION OF PLATE 92

All illustrations on this plate are unretouched photographs, and are magnified ×20.

FIG. *1–12—Wedekindellina ardmorensis*, n. sp. *1*. Axial section of the holotype, *2,7,10,11*, sagittal sections of paratypes; *3–6,9,12*, axial sections of paratypes; and *8*, tangential section of a paratype. *1,2,4–7* are of specimens 3, 7, 1, 5, 4, and 6, respectively. All are from the Confederate limestone, Ardmore Basin, Oklahoma (*1,2,4–7*, 0-101; *3,8–12*, 0-68).

Measurements of *Wedekindellina ardmorensis*, n. sp., in millimeters

Specimen	L.	W.	Ratio	Diam. of prol.	Height of volutions								Form ratio of volutions						
					1	2	3	4	5	6	7	8	1	2	3	4	5	6	7
1	4.3	1.2	3.6	.078	.031	.030	.054	.063	.087	.139	.131	—	1.2	1.6	2.2	2.4	2.6	2.9	3.0
2	3.9	1.3	3.0	.080	.047	.038	.038	.059	.087	.137	.204	—	1.0	1.7	2.1	2.2	2.4	2.4	2.6
3	4.5	1.7	2.7	.078	.023	.035	.054	.061	.087	.138	.177	—	1.0	1.5	2.0	2.1	2.2	2.7	2.5
4	3.6	1.5	2.4	.089	.019	.045	.057	.068	.110	.143	—	—	1.2	1.8	2.0	2.3	2.6	2.5	2.6
5	3.2	1.3	2.5	.084	.033	.045	.047	.075	.120	.139	—	—	1.1	1.7	2.2	2.8	3.0	3.5	—
6	—	1.4	—	.084	.035	.038	.044	.075	.078	.117	.132	.160	—	—	—	—	—	—	—
7	—	1.5	—	.070	.026	.056	.071	.106	.139	.197	—	—	—	—	—	—	—	—	—

Specimen	Thickness of spirotheca							Septal count							Tunnel angle (degrees)							
	1	2	3	4	5	6	7	1	2	3	4	5	6	7	1	2	3	4	5	6	7	8
1	—	.010	—	—	—	.028	—	—	—	—	—	—	—	—	—	—	—	24	29	40	37	—
2	—	—	—	—	—	.019	—	—	—	—	—	—	—	—	—	—	—	18	25	30	—	—
3	—	—	—	.010	.019	.021	.017	—	—	—	—	—	—	—	—	—	—	23	26	33	35	33
4	—	—	—	—	.016	.017	—	—	—	—	—	—	—	—	—	—	—	20	27	33	30	—
5	—	—	.007	.014	.019	—	—	—	—	—	—	—	—	—	—	—	—	29	37	39	56	—
6	—	—	.014	.019	.019	.021	.033	9	13	16	17	19	20	22	—	—	—	—	—	—	—	—
7	—	—	.014	.014	.023	.024	.028	8	12	14	18	19	21	21	—	—	—	—	—	—	—	—

Measurements of *Triticites winterensis*, n. sp., in millimeters

Specimen	L.	W.	Ratio	Diam. of prol.	Height of volutions								Form ratio of volutions							
					1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
1	8.1	2.6	3.1	.171	.047	.078	.115	.167	.219	.270	.391	—	1.6	1.7	1.8	1.7	2.4	2.1	2.8	—
2	6.6	2.7	2.4	.147	.035	.058	.090	.117	.176	.236	.272	.312	1.2	1.3	1.6	1.7	1.7	2.1	2.1	2.2
3	6.8	2.8	2.4	.160	.038	.085	.115	.172	.243	.385	.406	—	1.4	2.4	2.3	2.5	2.7	2.7	—	—
4	6.8	2.6	2.6	.152	.043	.059	.094	.120	.190	.237	.274	—	1.3	1.5	1.7	2.1	2.2	2.5	2.4	—
5	5.9	2.6	2.3	—	.043	.065	.092	.151	.197	.275	.300	.330	1.5	1.8	1.7	1.8	1.7	2.1	1.9	—
6	6.9	2.8	2.5	.125	.041	.082	.081	.126	.188	.274	.325	—	1.4	1.5	1.6	1.9	2.0	2.3	2.4	—
7	—	2.8	—	—	.046	.057	.079	.110	.146	.243	.304	.397	—	—	—	—	—	—	—	—
8	—	2.4	—	.164	.044	.059	.083	.105	.149	.228	.302	—	—	—	—	—	—	—	—	—
9	—	2.5	—	.128	.035	.058	.068	.102	.162	.197	.262	.280	—	—	—	—	—	—	—	—

Specimen	Thickness of spirotheca									Septal count								Tunnel angle (degrees)							
	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
1	—	—	.026	.027	.036	.056	.064	—	—	—	—	—	—	—	—	—	—	—	—	16	17	17	21	37	—
2	—	—	.020	.022	.031	.048	.056	.065	—	—	—	—	—	—	—	—	—	—	—	17	17	18	18	21	25
3	—	—	.026	.032	.044	.059	.066	—	—	—	—	—	—	—	—	—	—	—	—	19	25	34	38	50	—
4	—	—	.023	.028	.036	.060	.067	.047	—	—	—	—	—	—	—	—	—	—	—	17	20	24	28	31	—
5	—	—	.021	.028	.038	.058	.062	.061	.061	—	—	—	—	—	—	—	—	—	—	16	22	22	24	26	27
6	—	—	.018	.022	.029	.037	.059	—	—	—	—	—	—	—	—	—	—	—	—	—	17	22	21	26	—
7	—	—	.020	.021	.036	.044	.047	.066	—	11	17	21	28	30	33	39	46	—	—	—	—	—	—	—	—
8	—	—	.022	.024	.031	.038	.054	—	—	10	18	24	29	36	38	38	—	—	—	—	—	—	—	—	—
9	—	—	.019	.021	.034	.042	.057	.066	—	13	22	23	28	31	38	38	41	—	—	—	—	—	—	—	—

species of Pennsylvanian forms of the genus. Also, it differs from other Pennsylvanian forms of *Triticites* by its relatively thin spirotheca in comparison to the size of its shell.

It is not considered that *Triticites winterensis* was derived from a stock like most *Triticites* found in the lower part of American Missourian rocks. Furthermore, it is not considered to be ancestral to most later forms of the genus in America. However, a common ancestor may have given rise to *T. winterensis* and the numerous species and varieties which have been described from higher in the stratigraphic section, such as *T. osagenesis* (Newell), *T. neglectus* Newell, and others. All of these later species are very long and slender and they have irregularly and highly fluted septa throughout the length of their shells, and some of the group, such as undescribed species from the lower Virgilian, have axial fillings. However, if *T. winterensis* is related to these later species, the relationship is considered to be distant.

Occurrence.—*Triticites winterensis* is abundant in the middle part of the Winterset limestone at Wintereset, Iowa (I-44) where it is associated with common specimens of *T. ohioensis* and is less common in the upper part (I-50) and the lower part (I-53) of the same limestone where it is associated with abundant specimens of *T. ohioensis*.

REFERENCES

DUNBAR, C. O., & HENBEST, L. G., 1933, Fusulinidae (*In* Cushman, J. A. Foraminifera), p. 134, pl. 10, fig. 13–15.

FISCHER DE WALDHEIM, G., 1829, Les Céphalopodes fossiles de Moscou et de ses environs, en montrant ces objets en nature: Soc. naturalists Moscou, Bull., vol. 1, p. 300–362.

——, 1837, Oryctographie du Gouvernement de Moscou. p. 126,127, pl. 13.

MOORE, R. C., *et al.*, 1951, The Kansas rock column: Kansas Geol. Survey, Bull. 89, p. 1–132.

MÖLLER, V. VON, 1877, Ueber Fusulinen und ähnliche Foraminiferen-Formen des russischen Kohlenkalks: Neues Jahrb. Min., Geol. und Pal., Jahrg. 1877, p. 139–146, 1 fig.

NEWELL, N. D., & KEROHER, R. P., 1937, The fusulinid, *Wedekindellina*, in mid-Pennsylvanian rocks of Kansas and Missouri: Jour. Paleont. vol. 11, p. 698–705, pl. 93.

SCHELLWIEN, E., 1908, Monographie der Fusulinen. Teil I: Die Fusulinen des russisch-arktischen Meeresgebietes: Palaeontographica, Band 55, p. 145–194, pl. 13–20.

SILVESTRI, A., 1935, Sulla validità del genere "*Fusulina*" Fischer: Soc. Geol. Italiana, Boll., vol. 54, fasc. 2, p. 203–219, pl. 9.

THOMPSON, M. L., 1934, The fusulinids of the Des Moines series of Iowa: Iowa Univ. Studies Nat. History, vol. 16, p. 272–332, pl. 20–23.

——, 1936, The genotype of *Fusulina* s.s.: Am. Jour. Sci., 5th ser., vol. 32, p. 287–291.

——, 1942, Pennsylvanian system in New Mexico: New Mexico Bureau Mines, Bull. 17, p. 1–92.

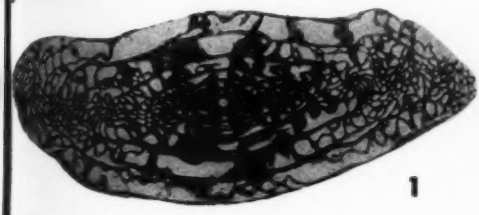
——, 1948, Studies of American fusulinids: Kansas Univ. Pal. Contr., Protozoa, Art. 1, p. 1–184, pl. 1–38.

——, 1951, New genera of fusulinid Foraminifera: Contr. Cushman Lab. Foram. Res., vol. 2, p. 115–119, pl. 13,14.

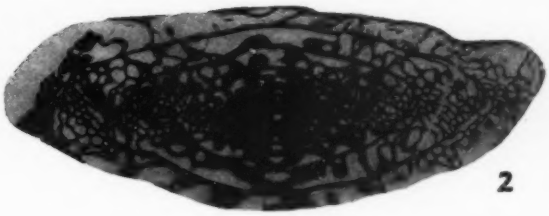
EXPLANATION OF PLATE 93

All illustrations on this plate are unretouched photographs, are magnified ×10, and are from the Winterset limestone at Winterset, Iowa (I-44)

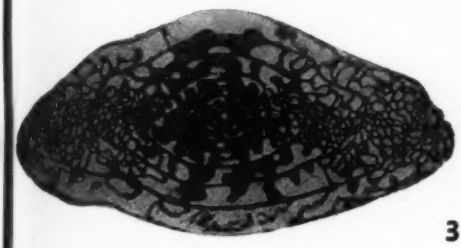
FIG. *1–13*—*Triticites winterensis*, n. sp. *1–5,9,10*, Axial sections of paratypes; *6,7*, tangential sections of paratypes showing septal fluting; *8*, axial section of the holotype; *11–13*, sagittal sections of paratypes. *1,4,5,8–13* are of specimens 4, 5, 3, 1, 6, 2, 9, 7, and 8, respectively.



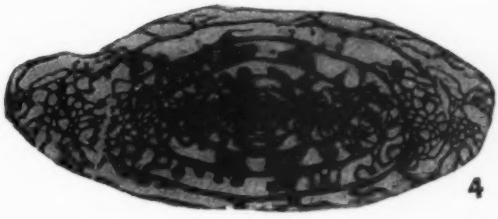
1



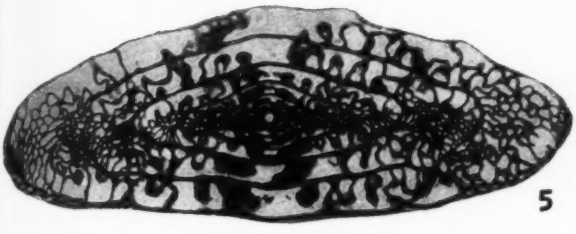
2



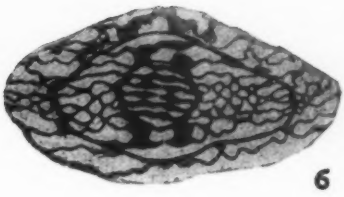
3



4

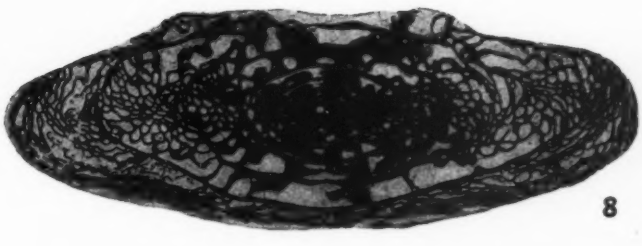


5



6

7

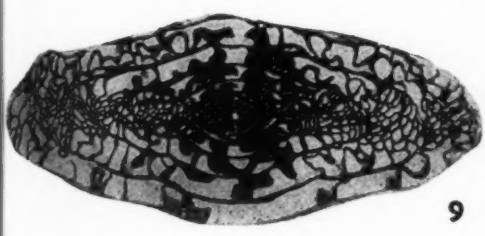


8

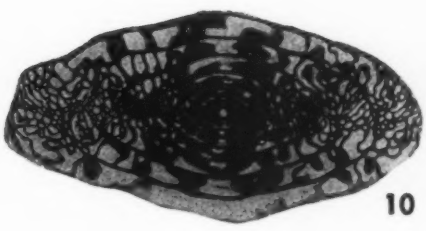
11

12

13



9



10

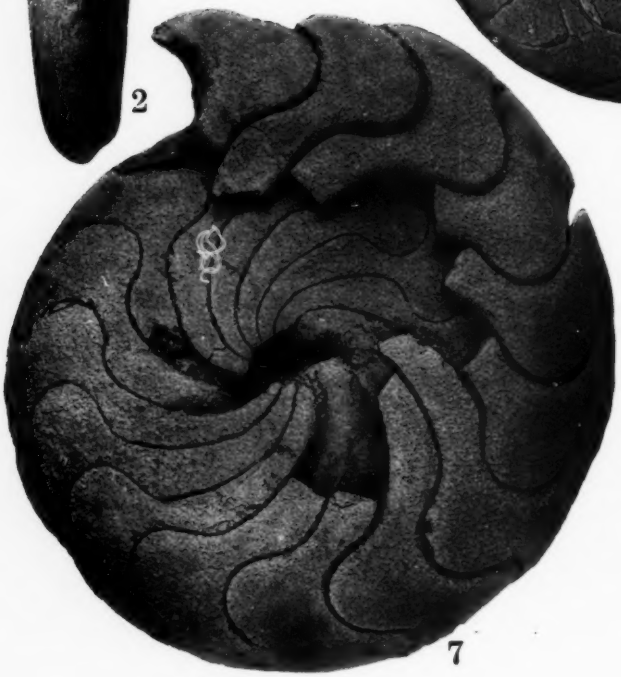
1

3

5

2

4



7

6

JOURNAL OF PALEONTOLOGY, VOL. 30, NO. 4, P. 811–817, PL. 94, 1 TEXT-FIG., JULY 1956

GONIATITES FROM THE MIDDLE DEVONIAN COLUMBUS LIMESTONE OF OHIO

WALTER C. SWEET AND A. K. MILLER
Ohio State University, Columbus; State University of Iowa, Iowa City

ABSTRACT—Representatives of the goniatite genera *Agoniatites*, *Werneroceras*, and *Tornoceras* are described from the early Middle Devonian Columbus limestone of Ohio. All of these genera are widely distributed in the Middle Devonian of Europe and North America. In this country, they represent a fauna known best from the Onondaga and lower Marcellus formations and their stratigraphic equivalents. *Werneroceras staufferi* S. & M., n. sp., and *Tornoceras* (*Tornoceras*) *eberlei* S. & M., n. sp., are herein described for the first time.

PRIMITIVE ammonoids, goniatites, are widespread in Devonian rocks, and the same genera are known to occur in both the Eastern and the Western hemispheres. This wide geographic distribution, together with the fact that these animals seem to have evolved rather rapidly along several different lines, make ammonoids valuable in stratigraphic work. In Europe, they are not uncommon in Lower Devonian strata, and the Middle and Upper Devonian series are subdivided into zones on the basis of their goniatite assemblages. However, in the Americas Devonian ammonoids are sporadic, and, for that reason, it is difficult to compare the Devonian sequence of the Western Hemisphere with the classic one of central Europe.

No Devonian ammonoids have been reported from South America, and in North America none are known from the Lower Devonian. The oldest American goniatites came from the Onondaga and its stratigraphic equivalents, but in strata of that age, these cephalopods are neither abundant nor well preserved. Furthermore, specimens referable to only two genera, *Agoniatites* and *Tornoceras*, have been described from the Onondagan (Miller, 1938; Oliver, 1956). Because early Middle Devonian ammonoids are rare in America, the fact that rather well preserved representatives of three genera have been found in rocks of Onondagan age in Ohio is of more than ordinary significance.

In central and west-central Ohio, the Middle Devonian limestones are divided into two formational units, which are recognizable in a narrow north-south belt extending from the southern shore of Lake Erie to about 25 miles south of Columbus in central Ohio. The older of the two formations, the Columbus limestone, is the thickest, reaching a maximum of 105 feet near Columbus, its type locality. In the southern part of its outcrop belt, the Columbus rests disconformably upon the upper Bass Island dolomite (Silurian), but in north-central Ohio it overlies older Devonian strata referable to some portion of the Detroit River group. For the most part, the lower half of the Columbus is composed of massive brown dolomitic limestone that contains few fossils except in its upper por-

EXPLANATION OF PLATE 94

All specimens illustrated on this plate are from the Columbus limestone of central Ohio. That represented by figures 3,4 is from the O'Shaunessy dam on the Scioto River, Delaware County; the others are from near Columbus, Franklin County.

FIG. *1,2*—*Agoniatites* aff. *A. vanuxemi* (Hall). Lateral and ventral views, ×¾.
3,4—*Tornoceras* (*Tornoceras*) *eberlei* S. & M., n. sp. Ventral and lateral views of the holotype, ×1¾.
5,6—*Werneroceras staufferi* S. & M., n. sp. Ventral and lateral views of the holotype, ×1.
7—*Tornoceras* (*Tornoceras*) *mithrax* (Hall.) Lateral view of the holotype, ×1.

tion, which apparently represents a coral and stromatoporoid biostrome. The upper half of the formation consists of somewhat thinner-bedded light-gray cherty limestone in which fossils are abundant and well preserved.

Throughout most of its area of exposure, the Columbus limestone is disconformably overlain by the Delaware limestone, which has an average thickness of about 36 feet in central Ohio and is typically composed of rather thin-bedded cherty bluish-gray limestone in which fossils are locally abundant. The Delaware is succeeded stratigraphically by the Olentangy and the Ohio shales, both of Upper Devonian age.

Nautiloid cephalopods are not rare in the Columbus limestone, but only a single goniatite, the holotype of *Tornoceras mithrax* (Hall), has heretofore been described from the formation. Stauffer (1909) listed *Agoniatites* [*Tornoceras*] *discoideus* (Hall) and "*Anarcestes* cf. *lateceptatus* Beyrich" as occurring in the Columbus, but his specimens have never been described or illustrated. In addition to one of Stauffer's specimens, the paleontological collections of the Ohio State University contain two additional goniatites which were collected from the Columbus limestone a number of years ago, but which have never been described, illustrated, or studied in detail. These four specimens are referable to *Agoniatites*, *Werneroceras*, and *Tornoceras*. Representatives of all these genera are not rare in eastern North America, and in some places they occur in considerable numbers in rocks of early Middle Devonian age. All three genera are present in the Cherry Valley member of the Marcellus formation (Miller, 1938), and *Werneroceras* has also been reported (Flower, 1943a) from the Union Springs member of the Marcellus, which lies immediately beneath the Cherry Valley limestone. A representative of *Agoniatites* has been described (Miller, 1938, p. 46–47) from the lower portion of the Roberts Mountain limestone of Nevada, which is about Onondagan in age, and Onondagan strata in New York, Maryland, and Pennsylvania have also yielded goniatites which are referable to *Agoniatites* and which are similar to the one from the Columbus limestone of Ohio.

In Europe, *Agoniatites* and *Werneroceras* are common in the *Anarcestes*-Stufe, the lowermost division of the Middle Devonian. *Agoniatites* ranges from the bottom to the top of the European Middle Devonian, and it may also occur in the Lower Devonian of that continent. *Werneroceras* is known to range from the early Middle Devonian (and probably the late Lower Devonian) into the lower portion of the Upper Devonian. *Tornoceras* has a stratigraphic range in Europe from the late Middle Devonian to the middle of the Upper Devonian, although Frech (1887) described three species from rocks of questionable Lower Devonian age in the Carnic Alps and France. In North America, however, *Tornoceras* is known to range from the base of the Middle Devonian well up into the Upper Devonian.

Although none of the Columbus goniatites belong in genera which have a particularly restricted stratigraphic range, they appear to be most closely related to species known best from rocks of early Middle Devonian age. The type specimens of *Agoniatites vanuxemi* (Hall), with which one of our Columbus goniatites is provisionally associated, came from the Cherry Valley member of the Marcellus formation in Onondaga County, New York; but other representatives of that species are known from exposures at Stony Point, Lake Erie, in beds which Cooper considers to be uppermost Onondagan (Senecan) in age. This fact, together with the presence of other Cherry Valley fossils in the western phase of the Onondaga, is taken by some (for example, Oliver, 1954) to indicate that the Onondaga "rises" in time to the west, so that its uppermost portion is equivalent to the lower Marcellus (Union Springs and Cherry Valley members) of the section to the east. *Agoniatites vanuxemi* has also been reported from the Onondagan portion of the Romney formation of Maryland, and from equivalent beds in Pennsylvania. Miller (1938, p. 54–55) expressed the opinion that these, as well as others reported from the Hamilton of New York and the Middle Devonian of Germany, are probably not closely related to the types of *A. vanuxemi*, which appears to occur only at the Cherry Valley horizon in the Devonian of eastern United States.

Werneroceras staufferi S. & M., n. sp., is

not particularly close to *W. plebeiforme* of the Union Springs and Cherry Valley members of the Marcellus, but it appears to be more like *W. subnautilus* (Buch) of the *Anarcestes*-Stufe of Germany and is of nearly the same age as the New York species. *Tornoceras* (*Tornoceras*) *eberlei* S. & M., n. sp., is related to *T.* (*T.*) *buttsi* Miller, the types of which came from Onondagan strata near Newcastle, Virginia. Other representatives of *T.* (*T.*) *buttsi* are also known from the Romney formation of Maryland, and Oliver (1956) has compared four large poorly preserved specimens from the Nedrow member of the Onondaga in east-central New York with the types of this species.

Tornoceras (*Tornoceras*) *mithrax* (Hall), the only goniatite previously described from the Columbus limestone, is a distinctive form which is not particularly close to any other species of the genus. This fact, of course, makes it difficult to assess its stratigraphic significance.

Stewart (1955, p. 160–179) has recently discussed the faunas and age relationships of the Columbus and Delaware limestones. She concluded that the Columbus is to be correlated with the upper Onondaga of New York and the Jeffersonville limestone of southeastern Indiana and northern Kentucky, and that the Delaware is the approximate stratigraphic equivalent of the Marcellus of New York. A study (Stewart & Sweet, 1956) of the conodont faunas of the Columbus and Delaware "bone beds" resulted in the same conclusion, and such a correlation is apparently consistent with earlier opinions expressed by Cooper *et al.* (1942) and by Ehlers *et al.* (1951, p. 26). It should be pointed out, however, that Flower (1943b) reports a "Hamilton" fauna in the upper part of the Columbus limestone, and two of the goniatites we are describing are probably closest to forms best known in North America from lower Marcellus strata. On the basis of four specimens, three of which are not precisely located within the formation, it would be presumptive for us either to affirm or attempt to revise the upper Onondagan age assignment currently accepted for the Columbus. However, these four specimens can be said to suggest that at least part of the Onondagan "phase" in central Ohio may be somewhat younger than the Onondaga of eastern New York, although perhaps not quite as young as the Union Springs or Cherry Valley members of the Marcellus.

We are grateful to Professor Norman D. Newell of Columbia University and the American Museum of Natural History for making the holotype of *Tornoceras mithrax* (Hall) available for study. Professor James M. Schopf of Ohio State University assisted with the photography, and most of the illustrations were retouched by Mr. Howard Webster of Iowa City.

SYSTEMATIC PALEONTOLOGY

AGONIATITES aff. A. VANUXEMI (Hall)

Pl. 94, fig. 1,2

The paleontological collections of the Ohio State University contain a rather poorly preserved but virtually complete representative of *Agoniatites*, which appears to be related to *A. vanuxemi* (Hall) but not to belong in that species. This specimen is an internal mold, which has a maximum overall measurement of 120 mm. and which represents at least four complete whorls of a laterally compressed sublenticular conch. The adoral half-volution is not septate and presumably represents body chamber. The conch expands orad rather rapidly, particularly in a dorso-ventral direction. At the adoral end of the body chamber, it is nearly three times as high as wide, although some of this difference may be due to diagenetic compression and weathering, which has removed considerable material from one side of the specimen. The dorsal side of the conch is deeply impressed by the ventral portion of the preceding volution, so that only about half of the inner volutions is visible in the umbilical region. The umbilicus is large, and apparently at maturity its diameter was equal to at least a fourth that of the specimen. The umbilical shoulders are indistinct, in part, at least, because of weathering.

Across the ventral and lateral zones of the specimen, there is a series of closely spaced fine lirae, which appear to have the same configuration as the growth lines of the types of *A. vanuxemi*. That is, the lirae form a rather deep ventral sinus, a broad

ventrolateral salient, a dorsolateral sinus, and a low salient centering on the umbilical shoulder.

At maturity, each suture forms a deep narrowly rounded V-shaped ventral lobe, a rounded asymmetrical ventrolateral saddle, a broad deep broadly rounded lateral lobe, and a somewhat narrower dorsolateral saddle which centers on the umbilical seam (Text-fig. 1D).

Remarks.—In general physiognomy, the specimen at hand resembles the types of *A. vanuxemi* (Hall). However, it is not possible to compare it in detail with Hall's species because we are uncertain as to the amount of post-depositional distortion, and parts of the conch have been restored by the collector. The sutures of our specimen seem to be close to those of the types of *A. vanuxemi*, but the venter is subangular (rather than flattened) and the umbilicus is relatively large. Consequently, the Columbus specimen is probably not referable to *A. vanuxemi*, a species which is known to be widely distributed in lower Marcellus strata in eastern United States, and which in western New York also occurs in rocks of Onondagan aspect but probably Marcellus age.

Occurrence.—Columbus limestone, Columbus, Ohio.

Repository.—Ohio State University Geological Museum, 3713.

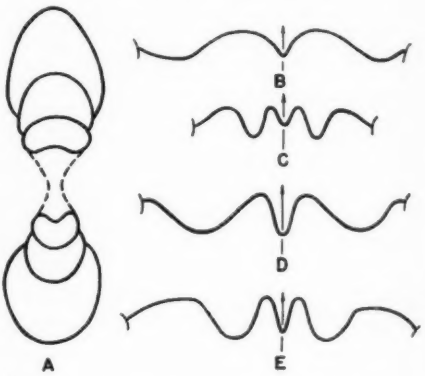
WERNEROCERAS STAUFFERI S. & M., n. sp.

Pl. 94, fig. 5,6

Anarcestes cf. *lateceptatus* STAUFFER, 1909, Ohio Geol. Surv., ser. 4, Bull. 10, p. 168,174.
?*Anarcestes lateseptatus* MILLER, 1938, Geol. Soc. Amer., Spec. Pap. 14, p. 5,57.
Anarcestes lateseptatus [cf. *Werneroceras plebiforme*] FLOWER, 1939, Palaeontogr. Americana, vol. 2, no. 10, p. 186(432).

A notation in the museum catalogue of the Ohio State University indicates that Stauffer identified two specimens from the Columbus limestone of central Ohio as "*Anarcestes* cf. *lateceptatus* Beyrich," and that the one we have been able to locate is the smaller individual. This specimen is septate throughout, and it represents at least four volutions of a subdiscoidal conch that is referable to *Werneroceras* Wedekind. However, it differs considerably from all previously described representatives of that genus, so we are proposing a specific name for it, in honor of Professor Clinton R. Stauffer, who, however, did not collect it.

This new species may be diagnosed as follows: Conch subdiscoidal, with rather gradually expanding, deeply impressed whorls. Later volutions are "helmet-shaped" in cross section, being distinctly higher than wide. Early volutions are wider than high, and are subelliptical to subcrescentic in outline. The umbilicus is wide, and apparently imperforate. The ontogenetic change in whorl outline is shown by Text-figure 1A, which represents diagrammatically a transverse section through the conch.



TEXT-FIG. 1—Diagrammatic section (*A*) across the whorls of *Werneroceras staufferi* S. & M., n. sp.; and mature external sutures of (*B*) *Werneroceras staufferi* S. & M., n. sp., (*C*) *Tornoceras* (*Tornoceras*) *eberlei* S. & M., n. sp., (*D*) *Agoniatites* aff. *A. vanuxemi* (Hall), and (*E*) *Tornoceras* (*Tornoceras*) *milhrax* (Hall); all ×½.

As shown by Text-figure 1B, the external suture forms a prominent V-shaped ventral lobe, broadly rounded lateral saddles, and shallow dorsolateral lobes which extend to the umbilical seams. Unfortunately, the nature of the internal suture can not be determined from the holotype.

On portions of the lateral zones, and particularly on the umbilical shoulders, there are poorly preserved traces of a series of closely spaced lirae, which presumably are an internal expression of the growth-line configuration. These lirae are virtually

parallel to the sutures on the umbilical shoulders, but, on the lateral zones, they swing strongly orad, apparently forming broad salients on the ventrolateral zones. None are preserved on the venter.

Remarks.—*Werneroceras* was established by Wedekind (1918, p. 107, 108) as a subgenus of *Anarcestes* Mojsisovics, to include forms similar in whorl outline to *Anarcestes s. s.* [in which the whorls are typically wider than high, at least at maturity] but differing from it in that the primary lateral lobe is subumbonal rather than lateral in position. More recent studies, particularly by Schindewolf (1933), have shown that *Werneroceras* and *Anarcestes* differ in a more fundamental way. That is, the first volution of *Anarcesters* is only loosely coiled about the protoconch, and the umbilicus is therefore perforate, whereas the first volution of *Werneroceras* is tightly coiled about the protoconch, resulting in an imperforate umbilicus.

Werneroceras staufferi S. & M., n. sp., is perhaps closest to the forms from the German Middle Devonian first described as "*Ammonites subnautilus*" by Buch (1832), later referred to *Anarcestes* by Beyrich (1844) and by Wedekind (1918), and provisionally assigned to *Werneroceras* by Miller (1938, p. 57). That is, both *W. staufferi* and *W.? subnautilus* have distinctly compressed (rather than depressed) outer whorls, and the sutures of both are similar to those of *W. ruppachense* (Kayser), the type species of *Werneroceras*. *W. staufferi* differs from both *W. plebeiforme* (Hall) and *W. wabashense* (Kindle), the only species of the genus heretofore reported from America, in that the height of its mature whorls exceeds their width. The Columbus species differs in detail from *W. plebeiforme* in that its sutures form well defined, though broadly rounded, lateral lobes, whereas the lateral lobes of *W. pleibeiforme* are poorly defined and are indicated only by a slight adapical flexure of the suture. *W. wabashense* has a more nearly comparable lateral suture, but the ventral lobe is very broad, and is therefore quite different from that of *W. staufferi*. Furthermore, on each quarter-volution of the conch, *W. wabashense* develops sinuous transverse ridges which parallel the growth lines. No such ornamentation is preserved on the holotype of *W. staufferi*, although faint impressions of growth lines can be seen on portions of the internal mold.

Occurrence.—Columbus limestone, near Columbus, Ohio. No detailed location or horizon within the Columbus is given on the label which accompanies the specimen.

Repository.—Holotype, Ohio State University Geological Museum, 11935.

TORNOCERAS (TORNOCERAS) EBERLEI S. & M., n. sp.
Pl. 94, fig. 3,4

The paleontological collection of the Ohio State University contain a well preserved representative of *Tornoceras*, which appears to represent a heretofore undescribed species. The label which accompanies the specimen indicates that it was collected from the Columbus limestone by Mr. Robert F. Eberle, in whose honor a name is proposed.

The holotype and only known representative of *Tornoceras* (*Tornoceras*) *eberlei* is a well preserved but incomplete internal mold, which is very slightly crushed laterally and which is septate throughout. Its maximum diameter, measured across the umbilicus, is 41 mm. The whorls are compressed, but are distinctly convex laterally, narrowly rounded ventrally, and deeply impressed dorsally. The outer volution expands from a height and width of 14 mm. and 12 mm. at its adapical end to comparable measurements of 22 mm. and 16 mm. at its adoral end, the point of maximum width being at the crest of the umbilical shoulder throughout the whorl. The camerae are relatively short, five occurring in the adoral third of the outer volution.

Traces of the surface ornamentation typical of *Tornoceras* are discernible on small fragments of the test which adhere to one of the lateral zones. This ornamentation consists of a series of fine very closely spaced transverse growth lines, which form prominent adorally-projecting salients on the ventrolateral zones, and deep adapically-directed sinuses on the venter.

The umbilicus is small but not closed, and its maximum diameter is 10 mm. The

umbilical shoulders are rather narrowly rounded.

Each suture (Text-fig. 1C) forms a rather small narrowly rounded V-shaped ventral lobe, on either side of which there is a small high U-shaped ventrolateral saddle. The ventral half of the lateral zone bears a deep narrow asymmetrical adventitious lobe, followed on the dorsal half of the lateral zone by a broadly arched asymmetrical saddle and a low rounded lobe which centers on the umbilical seam. The internal sutures of the holotype are not visible.

Remarks.—The small nearly closed umbilicus and the high prominent ventrolateral saddles of the sutures clearly indicate that this specimen should be referred to the subgenus *Tornoceras*. Among other described species placed in this group, *T.* (*T.*) *eberlei* compares most closely with *T.* (*T.*) *buttsi* Miller, representatives of which are known from Onondagan strata in Virginia, Maryland, and probably New York. Although the mature sutures of *T.* (*T.*) *eberlei* and *T.* (*T.*) *buttsi* are quite similar, the adventitious lateral lobes of the Columbus species are somewhat narrower than those of *T.* (*T.*) *buttsi*, and the first lateral lobes of *T.* (*T.*) *eberlei* center on the umbilical seam rather than on the dorsal portion of the dorsolateral zone. Both *T.* (*T.*) *eberlei* and *T.* (*T.*) *buttsi* are closely similar to the type species of the genus, *T.* (*T.*) *uniangulare* (Conrad), but they differ from it especially in that their umbilici are not quite closed.

Occurrence.—The holotype of *T.* (*T.*) *eberlei* was obtained from the upper portion of the Columbus limestone (Zone D of Stauffer, 1909), at the O'Shaunessy dam on the Scioto River, Delaware County, Ohio. It was almost certainly secured from strata exposed in a deep excavation cut through the Columbus limestone during the construction of that dam.

Repository.—Holotype, Ohio State University Geological Museum, 20232.

TORNOCERAS (TORNOCERAS) MITHRAX (Hall)

Pl. 94, fig. 7

Goniatites mithrax HALL, 1860, N. Y. State Cab. Nat. Hist., Ann. Rept. 13, p. 98, text-fig. 7.
Goniatites Mithrax HALL, 1876, N. Y. Geol. Surv., Illustrations of Devonian fossils, Cephalopoda, pl. 69, fig. 7; pl. 74, fig. 14. ——, 1879, Paleont. N. Y., vol. 5, pt. 2, p. 433–434, pl. 69, fig. 7; pl. 74, fig. 14. HYATT, 1884, Boston Soc. Nat. Hist., Proc., vol. 22, p. 321.
Goniatites mithrax WHITFIELD & HOVEY, 1900, Amer. Mus. Nat. Hist., Bull., vol. 11, p. 330–331.
Tornoceras (*Epitornoceras*) *mithrax* FRECH, 1902, Beitr. zur Paläont. u. Geol. Österreich-Ungarns u. Orients, Bd. 14, p. 51.
Tornoceras mithrax STAUFFER, 1909, Ohio Geol. Surv., ser. 4, Bull. 10, p. 169.
Tornoceras (*Epitornoceras*) *mithrax* FRECH, 1913, Fossilium Catalogus; I, Animalia, pars 1, p. 19.
Tornoceras (*Tornoceras*) *mithrax* MILLER, 1938, Geol. Soc. Amer,. Spec. Pap. 14, p. 153–154, pl. 25, fig. 9,10.

The only known representative of this species was secured long ago from the Columbus limestone near Columbus, Ohio, and was first described by Hall in 1860. It is an internal mold which is moderately well preserved in brown crinoidal dolomitic limestone but is worn on one side. It is septate throughout and therefore represents only phragmocone. Its maximum diameter, measured across the umbilicus, is about 90 mm., and it has an estimated maximum width of some 25 mm.

The conch is large and subdiscoidal. The whorls are compressed and flattened but are distinctly convex laterally, narrowly rounded ventrally, and deeply impressed dorsally. The conch expands rather gradually from a height of 35 mm. at the adapical end of the outer volution to a height of 50 mm. at the adoral end. The width cannot be determined accurately from the holotype, but in the outer volution it is equal to at least half the height of the conch. The umbilicus is small and closed, and the umbilical shoulders are rounded. No portion of the body chamber or the test and no trace of the growth lines are preserved.

The fourteen camerae in the outer volution of the phragmocone are moderate in size, and their length increases gradually and regularly throughout the outer volution. As shown by Text-figure 1E, each external suture forms a small deep narrow V-shaped ventral lobe and on either side of it a moderately high rather narrow very narrowly rounded ventrolateral saddle, a rather broad rounded U-shaped lateral lobe (an adventitious lobe), a broadly rounded asymmetrical lateral saddle, and a rather

shallow broad lobe (a first lateral lobe) on or near the umbilical seam. The siphuncle is small, ventral, and marginal.

Remarks.—The large size of this specimen is sufficient to distinguish it from almost all congeneric forms that have been described from America. Because its ventrolateral saddles are sharper, and the adjacent lobes deeper than is typical for the genus, Frech included this species in his subgenus *Epitornoceras*. However, both Schindewolf (1933, p. 103) and Miller (1938, p. 140) have expressed the opinion that the sutures of typical *Epitornoceras* and *Tornoceras* s. s. are not sufficiently different to justify recognition of two subgeneric groups.

Occurrence.—The holotype, the only known representative of this species, was obtained by a Doctor Mann from the Columbus limestone in the vicinity of Columbus, Ohio. No detailed locality or horizon within the formation is given on the label which accompanies the specimen, nor was such information mentioned by Hall in connection with his original description of the species.

Repository.—Holotype, American Museum of Natural History, New York, 4243/1.

REFERENCES

BEYRICH, ERNST, 1844, Erlaüterungen zu den Goniatiten L. v. Buch's: Zeitschr. deutsch. geol. Gesellsch., Bd. 36, p. 203–219.

BUCH, L. VON, 1832, Über Goniatiten: Physikal. Akad. Wiss. Berlin, Abh. (1830), p. 159–187, pl. 1–5.

COOPER, G. A., *et al.*, 1942, Correlation of the Devonian sedimentary formations of North America: Geol. Soc. Amer., Bull., vol. 53, p. 1729–1794.

EHLERS, G. M., *et al.*, 1951, Devonian rocks of southeastern Michigan and northwestern Ohio, [Geol. Soc. Amer., Detroit meeting field-trip guidebook], 40 p.

FLOWER, R. H., 1939, Study of the Pseudorthoceratidae: Paleontogr. Americana, vol. 2, no. 10, p. 1(247)–214(460), pl. 1(23)–9(31).

——, 1943a, Studies of Paleozoic Nautiloidea; Part II, *Werneroceras* in the Devonian of New York: Bull. Amer. Paleont., vol. 28, no. 109, p. 14–21, pl. 1.

——, 1943b, Middle Devonian nautiloids of New York [Abstract]: Geol. Soc. Amer., Bull., vol. 54, p. 1830.

FRECH, FRITZ, 1887, Ueber das Devon der Ostalpen, nebst Bemerkungen über das Silur und einem palaontologischen Anhang: Zeitschr. deutsch. geol. Gesellsch., Bd. 39, p. 659–738.

MILLER, A. K., 1938, Devonian ammonoids of America: Geol. Soc. Amer., Spec. Pap. 14, 262 p., 39 pl.

OLIVER, W. A., JR., 1954, Stratigraphy of the Onondaga limestone (Devonian) in central New York: Geol. Soc. Amer., Bull., vol. 65, p. 621–652.

——, 1956, *Tornoceras* from the Devonian Onondaga limestone of New York: Jour. Paleont., vol. 30, p. 402–405.

SCHINDEWOLF, O. H., 1933, Vergleichende Morphologie und Phylogenie der Anfangskammern tetrabranchiater Cephalopoden; Eine Studie über Herkunft, Stammesentwicklung und System der niederen Ammoneen: Abhandl. preuss. geol. Landesanstalt, N. F., Heft 148, 115 p., 4 pl.

STAUFFER, C. R., 1909, The Middle Devonian of Ohio: Ohio Geol. Surv., ser. 4, Bull. 10, 204 p., 17 pl.

STEWART, G. A., 1955, Age relations of the Middle Devonian limestones in Ohio: Ohio Jour. Sci., vol. 55, p. 147–181.

——, & SWEET, W. C., 1956. Conodonts from the Middle Devonian bone beds of central and west-central Ohio: Jour. Paleont., vol. 30, p. 261–273, pl. 33,34.

WEDEKIND, RUDOLF, 1918, Die Genera der Palaeoammonoidea (Goniatiten), (Mit Ausschluss der Mimoceratidae, Glyphioceratidae und Prolecanitidae): Palaeontographica, Bd. 62, p. 85–184, pl. 14–22.

JOURNAL OF PALEONTOLOGY, VOL. 30, NO. 4, P. 818–830, PL. 95, 96, JULY 1956

TRIASSIC CONODONTS FROM NEVADA

KLAUS J. MÜLLER
State University of Iowa, Iowa City

ABSTRACT—A conodont fauna, consisting of 17 species representing 11 genera, is described from the upper part of the Lower Triassic in Nevada. At least the more common genera have a long range and are identical with those in the Upper Paleozoic. All species, however, are previously undescribed and are quite distinct from those of the Permian as well as those from the Middle Triassic. A new family, Hibbardellidae, for compound bilaterally symmetrical forms is proposed, and a determination key is given. A new genus, *Ellisonia*, is described with *E. triassica*, n. sp., as type; its known range is Upper Devonian to Middle Triassic.

PREVIOUS STUDIES

TRUE Mesozoic conodonts have been mentioned in the literature only three times previously. None have been adequately described.

Branson & Mehl (1941a) figured and described briefly a few specimens of the genus *Gondolella* Stauffer & Plummer. These are stated to have come from the "Unterer Hauptmuschelkalk" or "Trochitenkalk," which is the lower part of the Hauptmuschelkalk, of Neustadt bei Weiblungen [or Weiblingen] and Harblinger, Germany. Dr. Linck of Gugglingen, Württemberg, has informed me that no town or village named "Neustadt bei Harblinger" (Branson & Mehl, p. 191) exists in this area; probably there was a mistake in spelling. Also, "Trochitenkalk" (crinoidal limestone) is lowermost Oberer Muschelkalk of lower Ladinian age, not Anisian, as Branson & Mehl (p. 194) suggested. These specimens were not considered by Branson & Mehl as constituting a valid record of Mesozoic conodonts, but rather as a residue from Pennsylvanian or Permian formations. However, they represent the only figured Mesozoic conodonts to date. They were regarded by Branson & Mehl (1941a, p. 194) as "very close to one that is present in the upper Phosphoria . . . of Wyoming. Ordinarily specimens from the two localities would be considered conspecific." In a later publication, however (1941b, p. 197), the same authors stated that "the species is not identical with any of the American forms."

Eicher (1946, 1947) has recorded an assemblage from the Gebel Araif el Naga,

EXPLANATION OF PLATE 95

All specimens, with exception of *12*, are from the Lower Triassic *Meekoceras* bed, Dinner Springs Canyon, northeastern Nevada. *12* is from the Middle Permian cephalopod limestone of Sosio Valley, Sicily. All figures are unretouched photographs, ×40.

FIGS. *1–9*—*Gondolella milleri* Müller, n. sp., *1–3*, paratype, dextral, upper, outer lateral, and lower views. *4–6*, holotype, dextral, upper, inner lateral, and lower views. *7*, paratype, dextral, inner lateral view. *8,9*, paratype, sinistral, upper and lower views.

10,11—*Gondolella eotriassica* Müller, n. sp., holotype, sinistral, upper and inner lateral views.

12—*Gondolella* sp., dextral, specimen from Sicily

13—*Neoprioniodus*? sp., outer lateral view. The anticusp is not preserved.

14–17—*Neoprioniodus bicuspidatus* Müller, n. sp., *14*, paratype. *15*, holotype. *16,17*, inner lateral and lower views of paratype.

18—*Neoprioniodus unicornis* Müller, n. sp., inner lateral view of holotype.

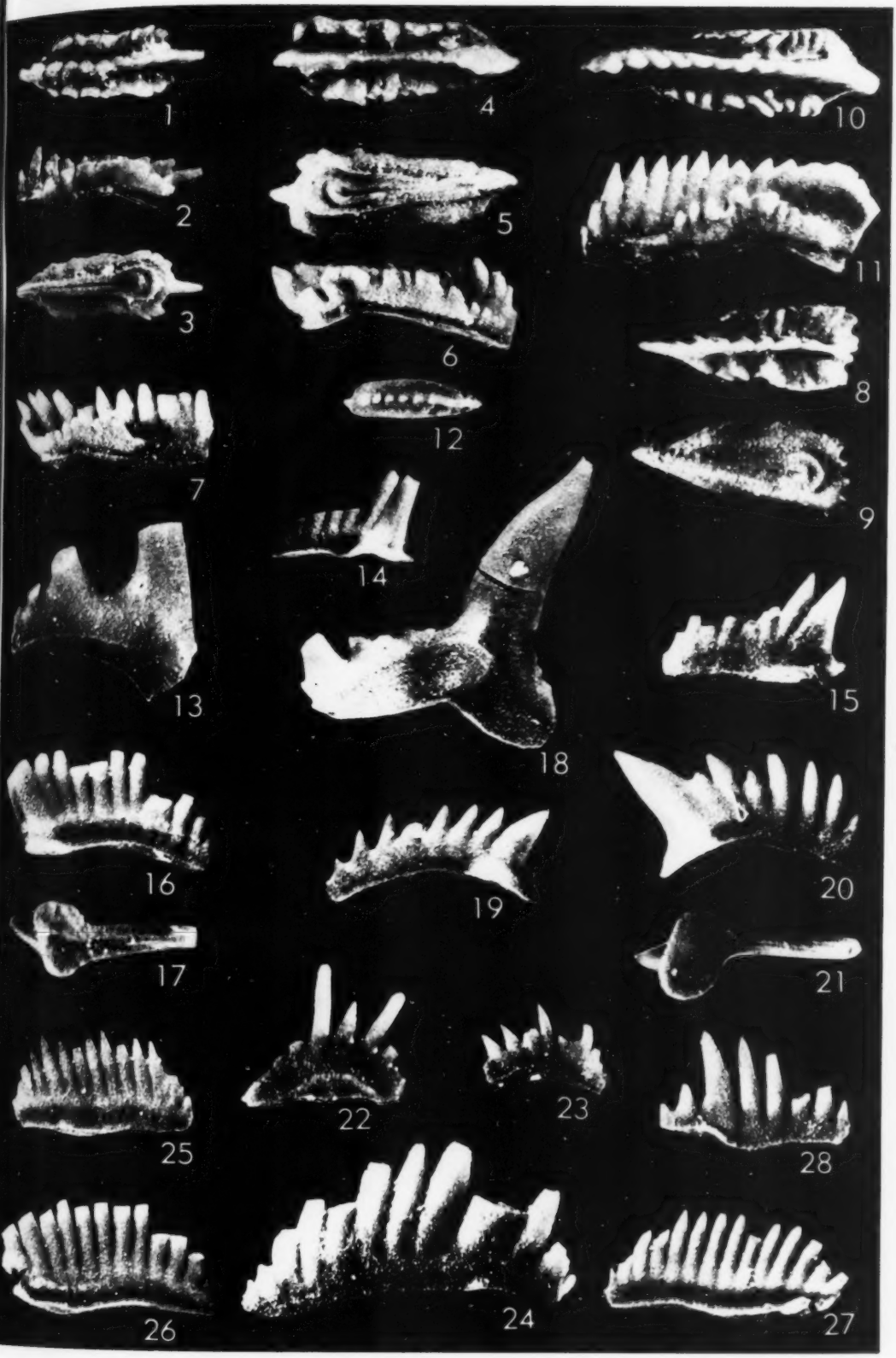
19–21—*Neoprioniodus bransoni* Müller, n. sp., *19*, inner lateral view of paratype. *20,21*, outer lateral and lower views of holotype.

22—Gen. indeterminable.

23—*Ozarkodina*? sp.

24,28—*Ctenognathus discreta* Müller, n. sp., paratype and holotype.

25–27—*Ctenognathus conservativa* Müller, n. sp., *25*, holotype. *26,27*, paratypes.


1
4
10
2
5
11
3
6
8
12
7
9
14
13
15
18
16
19
20
17
21
22
23
25
28
26
24
27

1
2
4
3
6
5
7
9
8
11
10
12
17
13
18
16
14

northeastern Sinai, near the Palestine border, which contains several different genera and species. The exact age of this formation can be determined through an associated molluscan fauna: *Progonoceratites* aff. *P. primitivus* Riedel or aff. *P. atavus* (Riedel), *Adontophora* aff. *A. münsteri* (Wissmann), *Myophoria laevigata* Alberg, *Ostrea montiscaprilis* Klipstein, and *Pseudoplacunopsis fissistriata* (Winkler). These fossils were found 3 m. and about 40 m. below the three shale horizons, which yielded conodonts. The megafauna shows a close similarity to the "upper Muschelkalk." Therefore the Sinai conodonts are of about the same age, but are probably somewhat younger than the "Trochitenkalk" conodonts in southern Germany.

The preliminary study of the conodonts by Eicher (1946, p. 613) "shows the presence, among others, of types similar to '*Euprioniodina*' and possibly '*Bryantodus*.' The ornamented leaf-shaped type of conodont found in many other older assemblages was not noted in the Araif el Naga fauna, but several specimens similar to '*Gnathodus*' approach the leaf like type."

Youngquist (1952) discusses conodonts secured from the high Lower Triassic (with *Columbites*-like forms and species resembling *Sibirites*), probably part of the Thaynes formation of the northeastern flank of the Bear River Range in southeastern Idaho. In this assemblage, which has been examined by various students, at least five genera are present. Ellison states, that the specimens "are like those described by Branson and Mehl from the Hauptmuschelkalk of Germany" and suggested that they are similar "to some of those . . . from the Phosphoria of Wyoming." The most common form is a *Gondolella*-like genus which is very similar to those of the Muschelkalk in Germany, according to Mehl, who added that "some of the others might well be long ranging Paleozoic types." Youngquist calls these forms "somewhat similar to *Ozarkodina*, and *Hibbardella* or *Trichognathus*." He states, that there are many differences between the Permian (Phosphoria) and Triassic specimens, and these two faunas on the basis of their platform-types alone would be easily distinguished and that this Triassic assemblage is quite distinct from previously described collections or individuals from Paleozoic strata.

METHODS AND MATERIAL

Paleozoic cephalopod-limestones, if they are sufficiently pure to dissolve in acetic acid, will yield (according to my experience with several hundred samples) at least a few conodonts 80% of the cases. In many cases the conodonts are not rare in this type of rock and, if carefully treated, nearly complete specimens can be obtained. Further, an

---

EXPLANATION OF PLATE 96

All specimens are from the Lower Triassic *Meekoceras* bed, Dinner Springs Canyon, northeastern Nevada. All figures are unretouched photographs, ×40.

FIGS. *1*—*Hindeodella raridenticulata* Müller, n. sp., holotype, sinistral, inner lateral view.
2,3—*Hindeodella nevadensis* Müller, n. sp., *2*, holotype, dextral, inner lateral view. *3*, paratype, dextral, inner lateral view.
4,5—*Hindeodella triassica* Müller, n. sp., *4*, paratype, dextral, inner lateral view. *5*, holotype, dextral, inner lateral view.
6—*Hindeodella*? sp.
7—*Lonchodina nevadensis* Müller, n. sp., inner lateral view of holotype.
8—*Lonchodus* sp.
9—*Lonchodina aequiarcuata* Müller, n. sp., inner lateral view of holotype.
10—*Lonchodina triassica* Müller, n. sp., inner lateral view of holotype.
11—*Hibbardella subsymmetrica* Müller, n. sp., holotype, inner lateral view.
12-14—*Ellisonia triassica* Müller, n. sp., upper, inner, and lateral views of holotype
15,16—*Ellisonia nevadensis* Müller, n. sp., oblique outer lateral and inner views of holotype.
17—*Ligonodina triassica* Müller, n. sp., holotype, sinistral, inner lateral view.
18—*Ozarkodina*? sp.

important advantage for studies of conodonts from this particular type of rock is that an exact age determination can be made with the cephalopods (especially ammonoids) and the biochronology of the two groups linked. The fact that conodonts are present in deposits of many other lithologic and facies types is well known. Their wide distribution in rocks where no other fossils are preserved (*e.g.*, black shales) makes them particularly valuable index fossils.

After it was established that Paleozoic cephalopods and conodonts are commonly associated, only two Triassic cephalopod limestone samples (in sufficient quantities) have been available to me for study. Both have produced good conodont faunas.

The material described in the present report was collected by W. M. Furnish & H. J. Trepagnier in the summer of 1954. The locality is T42N, R69E, Dinner Springs Canyon, about 1½ miles east of Crittenden Ranch, 18 miles north of Montello, Elko County, Nevada. A description of the section and a locality map is soon to be published by Clark & Stokes. The conodonts are from the ammonoid-bearing layer in this section, which is a gray pure dense limestone with a cephalopod fauna. The presence of an abundant and well preserved *Meekoceras*-zone fauna determines the age of this layer as late Lower Triassic.

The rock has been dissolved by applying little more than a stoechiometrically necessary quantity of 15% acetic acid. For the present report about 20 pounds of limestone, all that was available, was dissolved. The residue has been washed out very carefully on a 0.124 mm. 115 mesh, screen. The coarser part consists mostly of "steinkerns" of small gastropods and early growth stages of cephalopods, pyritized or transformed to iron oxide.

Conodonts are comparatively rare in this fauna and mostly very brittle. Fish scales are present but rare. The common association of conodonts with fish remains has been pointed out by Youngquist (1952, p. 653) who also has given a number of examples from the previous literature. My observations agree with his remarks, but, from the many residues I have studied, it is obvious that the distribution of conodonts is far wider than that of fish remains.

The other Triassic fauna which I have secured is from the Middle Triassic *Daonella dubia* zone of the Pit shale, American Canyon, western Nevada. The rock is a black limestone with many cephalopods and reptilian bone fragments. In this locality the conodonts are much more abundant than in Elko County of the same state, but they seem to be not as diverse in number of genera and species as in the *Meekoceras* horizon.

GENERAL APPRAISAL OF THE FAUNA

The fauna studied here consists of 11 genera, most of which are long ranging. One specimen, represented by Plate 95, figure 22, may belong to an undescribed genus with a shorter range. Since to date only little is known about Permian conodonts, it is possible that this form is present in, but not yet described from, older formations. As far as can be seen, there is no evidence affecting the evolution of conodonts at the boundary between Paleozoic and Mesozoic. The presence of clearly distinct species within several of the present "genera" (*Gondolella*, *Neoprioniodus*, *Hibbardella*, *Lonchodina*, *Hindeodella*) suggests that there may be present only a few "natural genera" but several species of these. In an Upper Devonian fauna, *e.g.*, one would expect a much greater generic variability from the same amount of material and the same number of species. Whether this fact is due to a recession of conodonts of this time or to local conditions can be shown only by examination of more abundant material from different horizons in the Triassic. The first possibility seems to be me the more likely, because the environment appears to be a favorable one.

Youngquist (1952, p. 652) has noted a general tendency in reduction of size, beginning in the Pennsylvanian and continuing through the Permian and into the Triassic. His observation was based particularly on the *Gondolella*-like genus, but also to a lesser extent on other conodonts. My material from the Middle Triassic Pit shale coincides well with this observation. In contrast, however, the fauna here described is not dwarfed. Perhaps this fact could be explained as the result of an especially favorable environment.

An evolutionary trend, concerned with the

reduction of the basal cavity in some genera is discussed on a following page. This trend is not limited to the Triassic, but the results of it are pronounced on the species of *Neoprioniodus* from this fauna.

Little can be said concerning the vertical range of the species described here. There are no species in common either with the older described faunas from the Permian and Pennsylvanian or, as far as can be seen, with the younger Pit shale. The possibility of an application as time makers within the Triassic can be expected.

There is a remarkable similarity between the *Gondolella* from the Muschelkalk of Germany, figured by Branson & Mehl, and those of the Pit shale. As is customary with other conodont faunas as well as cephalopods, the difference in age seems to be more important for the differentiation of the forms than the great distance between localities.

ACKNOWLEDGMENTS

I am most grateful to Professors A. K. Miller and W. M. Furnish for editorial and advisory help. The latter collected the limestone samples dissolved to secure the conodonts. My stay in the United States has been made possible by a research fellowship of the National Academy of Science-National Research Council together with the International Cooperation Administration. The use of the facilities of the State University of Iowa made it possible for me to prepare this report. It should also be stated that the author is on leave from the Technische Universität Berlin-Charlottenburg.

The National Academy of Science provided funds for the photographic materials. Dr. O. Linck, Gugglingen, Württemberg, Germany has given me information concerning the locality in the reports of Branson & Mehl (1941). My wife, Eva Müller, prepared the samples, picked the conodonts, and helped with the photography.

All figured specimens are deposited at the State University of Iowa (SUI).

SYSTEMATIC DESCRIPTIONS

Genus CTENOGNATHUS Pander, 1856

As recognized by Gross (1954) *Spathognathodus* Branson & Mehl, 1948 [=*Spathodus* Branson & Mehl, 1934; *non* Boulenger, 1900], is without doubt a junior synonym of *Ctenognathus*. This genus ranges from the Silurian into the Triassic and is regarded as the ancestor of most of the platform types. It is common in the present fauna, in contrast to its rare occurrence in Pennsylvanian (Ellison, 1941, p. 120). To date no representatives of *Ctenognathus* have been described from the Permian, and therefore the ranges of the following species are not known.

CTENOGNATHUS CONSERVATIVA Müller, n. sp.
Pl. 95, fig. 25–27

Limb a little undulated and relatively high. About 12 regular strongly laterally compressed denticles that are long and narrow, with only the pointed tips discrete. The denticles are inclined forward a little, and there are no germ denticles. Because the limb is extremely narrow, there is almost no lower surface developed. An indication of an escucheon and a flat furrow is present in the anterior half of the unit.

Occurrence.—Lower Triassic cephalopod bed, T42N, R69E; Dinner Springs Canyon, about 1½ miles east of Crittenden Ranch, 18 miles north of Montello, Elko County, Nevada.

Types.—Holotype, SUI 2250 (Pl. 95, fig. 25); figured paratypes, SUI 2251, 2252 (Pl. 95, fig. 26,27); unfigured paratypes, SUI 2253.

CTENOGNATHUS DISCRETA Müller, n. sp.
Pl. 95, fig. 24,28

Limb relatively flat and extremely thin. Denticles fully discrete, laterally compressed and inclined somewhat forward. Largest denticle located near the middle, with a decrease in height anteriorly and posteriorly. The largest denticles are a little more inclined than the other ones. No germ denticles are present. The escutcheon is located in the first third of the unit.

Most probably the large figured specimen (Pl. 95, fig. 24) belongs to this species, but in this individual the space between the denticles has been filled by the lateral growth of the denticles, which are fused except for the tips. The escutcheon is near the front, somewhat anterior to the largest denticle.

Remarks.—This species differs from *C.*

conservativa Müller, n. sp., in that it has fewer denticles, which are also fully discrete instead of fused in comparable growth stages. In addition, the escutcheon is more anterior in position.

Occurrence.—Lower Triassic cephalopod bed, T42N, R69E; Dinner Springs Canyon, about 1½ miles east of Crittenden Ranch, 18 miles north of Montello, Elko County, Nevada.

Types.—Holotype, SUI 2254 (Pl. 95, fig. 28); figured paratype, SUI 2255 (Pl. 95, fig. 24); unfigured paratypes, SUI 2256.

Genus ELLISONIA Müller, n. gen.

Type species.—*E. triassica* Müller, n. sp.

Diagnosis.—A bilaterally symmetrical unit with a large main cusp, which is more or less curved posteriorly. The two lateral limbs are directed forward adjacent to the cusp, but the tips are curved backward. There is one well developed denticulate median posterior bar. Denticles on the bar and limbs are discrete. Between the first-order denticles, there may be smaller second-order denticles. There is no basal cavity.

This genus differs by the lack of a basal cavity from *Roundya* Hass, 1953, which has a large cavity; and from *Hibbardella* Ulrich & Bassler, 1925, by the presence of a big denticulate posterior bar. *Trichonodella* Branson & Mehl, 1948, has a very well developed basal cavity and no denticulate posterior bar. In this restricted sense, *Trichonodella* seems to be confined to the Ordovician and Silurian, and probably it is the ancestor of *Hibbardella*.

Occurrence.—*Ellisonia* is fairly common in the Upper Devonian; it ranges into the Middle Triassic.

ELLISONIA TRIASSICA Müller, n. sp.
Pl. 96, fig. 12–14

Main cusp relatively small, curved posteriorly and pointed. Symmetrical side-limbs are less than half as long as the median posterior bar. The angle between the side-limbs, measured on their lower limits, is about 130°. The bars are high and adorned with big rounded discrete denticles. There are neither germ denticles nor second-order denticles. The limit between the lower and upper surface is distinct. The well developed lower surface can be distinguished by its darker color, and it is sharply keeled. There is no pit or groove beneath the main cusp. The posterior bar is very stout and high; its denticles are somewhat laterally compressed on its base and rounded near the pointed tips. The denticles of the posterior bar are progressively inclined posteriorly; the largest is near the end. There is a relatively large gap between the main cusp and the first posterior denticle.

Occurrence.—Lower Triassic cephalopod bed, T42N, R69E; Dinner Springs Canyon, about 1½ miles east of Crittenden Ranch, 18 miles north of Montello, Elko County, Nevada.

Types.—Holotype, SUI 2257 (Pl. 96, fig. 12–14); unfigured paratype, SUI 2258.

ELLISONIA NEVADENSIS Müller, n. sp.
Pl. 96, fig. 15,16

Main cusp relatively small, curved posteriorly. Symmetrical side-limbs very long and high with a sharp angle between them, about 45°. The bars are adorned with numerous short, discrete anterior-posteriorly compressed denticles. There are neither germ-denticles nor second-order denticles. The upper margin of the small lower surface is fairly well marked by a line parallel to the lower limit at a distance of about one-fourth the height of the side-limbs. There is no pit or groove beneath the main cusp. There is no marked gap between the main cusp and the first of the denticles, which are similar to those of the side-limbs, but laterally compressed.

Remarks.—This species can be distinguished from *E. triassica* by the longer side-limbs with small denticles as well as by the sharp limb-angle. Most of the posterior bar is not preserved in the type.

Occurrence.—Lower Triassic cephalopod bed, T42N, R69E; Dinner Springs Canyon, about 1½ miles east of Crittenden Ranch, 18 miles north of Montello, Elko County, Nevada.

Holotype.—SUI 2259 (Pl. 96, fig. 15,16).

Genus GONDOLELLA Stauffer & Plummer, 1932

Both species in the present fauna are highly specialized forms and very unlike

those from the Permian Phosphoria of southern Idaho and from the Sosio Valley of Sicily, as well as those from the Middle Triassic Muschelkalk (Branson & Mehl, 1941a) and Pit shale. With the exception of one fragmentary specimen from the Phosphoria (Youngquist, Hawley, & Miller, 1951, pl. 54, fig. 20) all known Permian forms have a smooth platform surface without sculpture. However, most of the Pennsylvanian species are adorned with more or less well developed ridges. Both Lower Triassic species, here described, also have well developed sculpture, but they are nevertheless easy to distinguish from the older ones. It is not clear at the present time if there is a phylogenetic connection between the forms of the Pennsylvanian and the Lower Triassic or if this similarity is due to an analogous appearance of a similar pattern within different branches of the group. The latter possibility seems to be the more likely.

In the orientation of *Gondolella*, I am following previous workers and regard the part with the cusp and the loop on the lower surface as posterior, the pointed part as anterior. This orientation is artificial and does not coincide with the orientation of most genera, in which the main cusp is regarded as anterior.

The tissue which formed this conodont covered its upper surface, but, as in most platform types, covered part of the lower surface also. The part of the lower surface covered by the tissue is called the "crimp." It can be distinguished by a smooth and shiny surface and differs from the adjoining duller part, which was covered by a supporting tissue. In *Gondolella* the crimp is extremely broad.

Occurrence.—The known range of this genus is from the Pennsylvanian (post-Bendian) into the Middle Triassic. There were developed some relatively short-lived species, which can be used as index fossils.

GONDOLELLA MILLERI Müller, n. sp.
Pl. 95, fig. 1–9

Unit subsymmetrical, relatively short and compact. The greatest width of the platform is near the posterior end of the specimen. The subparallel sides of the platform converge to a point in the anterior third. The rim is bowed upward strongly, in some cases medianly up to the height of the central carina; and it is ornamented by an irregular sculpture of nodes. Ordinarily there is no connection between these nodes and the carina, for a deep groove exists between. The carina is high and very little bowed, so that there are "dextral" and "sinistral" forms. The denticles are irregular in size and form, laterally compressed and relatively long. There are 9–12 denticles, with the number increasing according to the size of the conodont. There are no germ denticles. The denticles are progressively inclined posteriorly.

The cusp has about the same size, or is a little higher, than the highest denticles in front. The denticles in the middle part of the unit are a little smaller than those near the ends and are somewhat fused. Laterally there is a very well developed regular furrow which surrounds the loop and the keel up to the front. On the lower surface the platform is smooth, the crimp covers all the space between rim and furrow. The double keel with basal groove is relatively broad and more or less uniformly tapered anteriorly. The loop is asymmetric and is more pronounced on the inner side.

Occurrence.—Lower Triassic cephalopod bed, T42N, R69E; Dinner Springs Canyon, about 1½ miles east of Crittenden Ranch, 18 miles north of Montello, Elko County, Nevada.

Types.—Holotype, SUI 2260 (Pl. 95, fig. 4–6); figured paratypes, SUI 2261, 2262, 2263 (Pl. 95, fig. 1–3,7,8–9).

GONDOLELLA EOTRIASSICA Müller, n. sp.
Pl. 95, fig. 10,11

Unit asymmetric and elongate. The greatest width of the relatively small platform is near the posterior. The platform converges anteriorly and does not reach the tip of the carina. Its surface is adorned on its rim by large elongate irregular nodes which, in the middle of the platform, are inclined a little forward. A deep groove extends on both sides of the carina. The carina is extremely high and somewhat bowed inward anteriorly. The denticles are subregular in size and form, compressed laterally, and long, but only the pointed tips are discrete. Toward the posterior they

are fused. The holotype has 16 denticles; germ denticles are not present.

The furrow, which surrounds the loop, is faint and disappears anteriorly. The loop is large and flat, its outer boundary coincides with the inner limit of the crimp, which is very broad.

Occurrence.—Lower Triassic cephalopod bed, T42N, R69E; Dinner Springs Canyon, about 1½ miles east of Crittenden Ranch, 18 miles north of Montello, Elko County, Nevada.

Types.—Holotype, SUI 2264 (Pl. 95, fig. 10,11); unfigured paratype, SUI 2265.

GONDOLELLA n. sp.
Pl. 95, fig. 12

To date, the only Permian conodonts that have been described are from the Phosphoria. Therefore, I am including an illustration and a description of this form from the Middle Permian of the Sosio Valley near Palermo, Sicily. It was secured, together with a few others belonging in *Hindeodella* and a *Gnathodus*-like genus, by dissolving small pieces of light yellow cephalopod-bearing limestone from this well known locality.

The unit is subsymmetric elongate lanceolate relatively strongly arched and nearly straight. Main cusp small and inclined posteriorly; carina has 8–9 denticles, which become considerably higher anteriorly, but more laterally compressed, pointed and somewhat inclined posteriorly. Platform smooth; its rim is slightly higher than its middle part near the carina. Lower ("aboral") side has near its middle a narrow elongate escutcheon, which becomes broader posteriorly and forms a small symmetrical loop beneath the cusp.

Remarks.—This species resembles *G. idahoensis* Youngquist, Hawley, & Miller, 1951, from the early Middle Permian Phosphoria of southeastern Idaho. It may be distinguished from that form by the following features: the entire unit is more strongly arched; the denticles are higher and particularly the last 3–4 are laterally compressed, more pointed, and directed forward; and the escutcheon is narrower.

Figured specimen.—SUI 2266 (Pl. 95, fig. 12); unfigured specimens, SUI 2267.

Family HIBBARDELLIDAE Müller, n. fam.

Diagnosis.—Bilaterally symmetric, not paired, compound conodonts with a large main denticle. These units have apparently been arranged in the median line of the animal. A median branch may or may not be present.

Remarks.—The increasing number of described genera makes it desirable to establish also additional suprageneric taxa to facilitate determinations. In many of the original descriptions, the symmetry of the genera belonging in this family has been noted. The systematic importance of bilateral symmetry has been recognized also by Lindström (1954, p. 540) who states: "To attain an objective classification of conodonts one must pay attention to such absolute characters as costae and denticles and, to some extent, symmetry." Furthermore, that author uses this feature in an artificial key for simple cones. It seems that it is an even more stable character in the compound forms, which were probably derived from bilaterally symmetric simple cones.

The Hibbardellidae includes the following genera (of which the type species are cited):

Hibbardella Ulrich & Bassler, 1925
[**Prioniodus angulatus* Hinde, 1879]
Trichonodella Branson & Mehl, 1948
[**Trichognathus prima* Branson & Mehl, 1933]
Diplododella Ulrich & Bassler, 1925
[**D. bilateralis*]
Elsonella Youngquist, 1945
[**E. prima*]
Roundya Hass, 1953
[**R. barnettana*]
Tripodellus Sannemann, 1955
[**T. flexuosus*]
Ellisonia Müller, n. gen.
[**E. triassica*]

Remarks.—As in many of the other genera of Ulrich & Bassler, *Hibbardella* was established in an abstract (Bassler, 1925, p. 218). Because the date of publication antedates 1930, this procedure constitutes a valid introduction for the names (Art. 8, Internat. Rules of Zoological Nomenclature). There is some question as to authorship, but the intentions of Bassler seem to be clear as he stated: "Excellent series of conodonts have been accumulated in the United States National Museum collections by E. O. Ulrich and the writer during the past 25 years, [which] caused *us* [emphasis added] to take up the present work." The names in

this paper are therefore to be attributed to Ulrich & Bassler, *in* Bassler, 1925.

Trichognathus Branson & Mehl [*non* Gemminger & Harold, 1868] was proposed in 1933, and *T. prima* B. & M. was designated type; though in 1944 the authors listed their species *T. symmetrica* as type. In 1947 Branson & Branson employed *Trichonodella* for comparable forms without explanation. Rhodes (1953, p. 312) supposed that the replacement of the name *Trichognathus* was established with its first use (Branson & Branson, 1947), and he has chosen from the species in this paper *T. brassfieldensis* as type. However, the new name was not actually proposed in 1947, for Branson & Branson have not defined the name and it was therefore a nomen nudum at that time. *Trichonodella* was established by Branson & Mehl, 1948 (p. 527) as a substitute for their preoccupied name, *Trichognathus* 1933. According to Article 30f of the International Rules of Zoological Nomenclature, the type species of *Trichonodella* is *Trichognathus prima* B. & M.

Diplododella has been misspelled *Diplodella* by a number of authors.

A reexamination of the type specimens of the type of *Elsonella, E. prima,* has shown that this species has a median branch, which is partly broken off the holotype, but is present on one paratype. The only figure of the holotype (1945, pl. 56, fig. 5), shows the specimen from the front, and therefore the stub of the median branch is not visible. *Elsonella secunda* has no bilateral symmetry and therefore is to be excluded from the genus.

Neither in the original diagnosis of *Tripodellus* nor in the description of the type species has the symmetry been noted. The figures, however, seem to indicate clearly, that this genus has a pronounced bilateral symmetry.

DETERMINATION KEY TO GENERA OF HIBBARDELLIDAE

1. Basal cavity large 2
   Basal cavity restricted or absent 4
2. With median branch 3
   Without median branch . . . . . *Trichonodella* [Ordovician-Silurian]
3. Denticles discrete . . . . . *Roundya* [(Ordovician?); Pennsylvanian]
   Denticles fused . . . *Elsonella* [Upper Devonian]
4. Lateral branches with one row of denticles . . 5
   Lateral branches with two or more rows of denticles . . . *Diplododella* [Upper Devonian]
5. Without anterior median branch 6
   With anterior median branch . . . . . *Tripodellus* [Upper Devonian]
6. Without median branch . . . . . *Hibbardella* [(Ordovician?); Devonian-Lower Triassic]
   With posterior median branch . . . . . *Ellisonia* [Upper Devonian-Middle Triassic]

Remarks.—The range of the genera is tentative and represents only the present status of knowledge; many species cannot be assigned definitely because of inadequate description.

Genus HIBBARDELLA Ulrich & Bassler, *in* Bassler, 1925

The restudy of Hinde's type specimen of *Prioniodus angulatus* in the British Museum by Branson & Mehl (1933b, p. 141), and material from the type locality, sent to me by Mr. R. R. Hibbard shows very clearly that this species has a relatively wide apron, a shallow basal cavity, and no posterior bar. The figures by Ulrich & Bassler (1926, pl. 3, fig. 1,2,4 [Fig. 3 is not regarded as belonging to this species]), and Youngquist, Hibbard & Reimann (1948, pl. 15, fig. 2,13) are made from the front view, which is most often preserved on the bedding surfaces of the Rhinestreet shale. Their illustrations, therefore, do not show the diagnostic features. The furrow on the main cusp, which is very well developed on this species, seems to me not significant for the genus as a whole.

HIBBARDELLA SUBSYMMETRICA Müller, n. sp.

Pl. 96, fig. 11

Unit subsymmetrical, main cusp large and very long, circular in cross section, pointed and strongly bowed posteriorly. Limbs subsymmetrical; on each side are 3–4 long rounded and discrete denticles which are bowed posteriorly and which increase markedly in size toward the main cusp. On one side they are much stronger and are more than twice as large as on the other; therefore, the outline of this species is somewhat asymmetrical. Main cusp has on the inner side of its basal cavity a well developed flared apron. The basal cavity is developed only as a shallow depression which can be distinguished by a darker color from the remainder of the conodont.

Occurrence.—Lower Triassic cephalopod bed, T42N, R69E; Dinner Springs Canyon, about 1½ miles east of Crittenden Ranch, 18 miles north of Montello, Elko County, Nevada.

Types.—Holotype, SUI 2268 (Pl. 96, fig. 11); unfigured paratypes, SUI 2269.

Genus HINDEODELLA Ulrich & Bassler, 1925

Two of the species belonging with certainty in this genus have relatively high bars. The same is true for a single specimen of *Hindeodella* known from the Middle Permian of Sicily. More material may indicate that there is a general tendency toward this characteristic in the youngest forms of the genus. The reason for citing this genus under the date 1925 is given under remarks on Hibbardellidae.

HINDEODELLA NEVADENSIS Müller, n. sp. Pl. 96, fig. 2,3

Bar relatively short and stout, strongly arched and large. The anterior limb is only a little bowed inward. Denticles large, discrete, widely spaced, and somewhat irregular in size and distribution. They are laterally compressed at the base and nearly circular in cross section at the tip, and are somewhat bent posteriorly. There are no germ denticles. Near the end, the denticles are small and fused. Main cusp very large, bent posteriorly, and slightly bowed inward. The lower surface is relatively broad and distinguished by a darker color. On the specimen represented by Pl. 96, fig. 3, there is a small basal enlargement, which is lacking on the holotype.

Remarks.—This species can be distinguished from *H. triassica* Müller, n. sp., by the fewer and stouter denticles and by the well developed lower surface.

Occurrence.—Lower Triassic cephalopod bed, T42N, R69E; Dinner Springs Canyon, about 1½ miles east of Crittenden Ranch, 18 miles north of Montello, Elko County, Nevada.

Types.—Holotype, SUI 2270 (Pl. 96, fig. 2); figured paratype, SUI 2271 (Pl. 96, fig. 3); unfigured paratypes, SUI 2272.

HINDEODELLA TRIASSICA Müller, n. sp. Pl. 96, fig. 4,5

Bar minute, relatively short, high, and somewhat arched; anterior limb short and only slightly bowed inward. Denticles discrete, pointed, strongly laterally compressed, and irregular. On the anterior part there are a few large denticles. On both bars the largest denticles are near the ends, whereas in the vicinity of the main cusp there are only small ones. The denticles are progressively inclined posteriorly. Even through transmitted light, there are no germ denticles visible. Main cusp more than three times as large as the largest denticle. The bar is very thin; the lower surface is correspondingly small. There is no pit or groove beneath the main cusp.

Occurrence.—Lower Triassic cephalopod bed, T42N, R69E; Dinner Springs Canyon, about 1½ miles east of Crittenden Ranch, 18 miles north of Montello, Elko County, Nevada.

Types.—Holotype, SUI 2273 (Pl. 96, fig. 5); figured paratype, SUI 2274 (Pl. 96, fig. 4); unfigured paratype, SUI 2275.

HINDEODELLA RARIDENTICULATA Müller, n. sp. Pl. 96, fig. 1

Bar minute, short, and low; slightly tapered toward the posterior end. Anterior limb short and only very little bowed inward. Denticles very large, discrete, pointed, and laterally compressed. There are no germ denticles developed. On the anterior limb there are only two denticles, and on the posterior limb of the holotype there are three, which are progressively inclined posteriorly. The largest denticle is nearly two-thirds as large as the main cusp. Lower surface small and without a groove.

Occurrence.—Lower Triassic cephalopod bed, T42N, R69E; Dinner Springs Canyon, about 1½ miles east of Crittenden Ranch, 18 miles north of Montello, Elko County, Nevada.

Holotype.—SUI 2276 (Pl. 96, fig. 1).

HINDEODELLA? sp. Pl. 96, fig. 6

This form has a strongly arched but not laterally bowed bar. The large laterally compressed main cusp is bent posteriorly, and a very little inward. The denticles are large and discrete with wide gaps between. The lower surface is fairly well developed and its

upper limit forms a line parallel to the growth axis.

Remarks.—Because the anterior part of bar is not bowed inward, this form cannot be regarded without doubt as a true *Hindeodella*. The posterior portion of the bar is not preserved in the figured specimen.

Occurrence.—Lower Triassic cephalopod bed, T42N, R69E; Dinner Springs Canyon, about 1½ miles east of Crittenden Ranch, 18 miles north of Montello, Elko County, Nevada.

Figured specimen.—SUI 2277 (Pl. 96, fig. 6).

Genus LIGONODINA Ulrich & Bassler, 1925

The genus is represented in the *Meekoceras* limestone with a very highly advanced species. The reason for citing this genus under the date 1925 is given under remarks on Hibbardellidae.

LIGONODINA TRIASSICA Müller, n. sp. Pl. 96, fig. 17

The main cusp is well developed, oval in cross section at the base, and bent posteriorly. There is no furrow on the main cusp. Posterior limb about twice as long as anterior limb. The limbs are laterally compressed and relatively high. The angle between anterior and posterior limbs is about 160°, relatively obtuse. In cross section, denticles are elongate-oval at the base and circular in their upper portion, being very widely spaced. There are three denticles on the anterior limb; these are irregular in size and bent posteriorly; there are five denticles on the posterior limb, which are recurved and progressively inclined posteriorly. As is common in other representatives of *Ligonodina*, there is a large gap between the main cusp and the first denticle. There is no apron beneath the base of the cusp. The contact between upper and lower surfaces is very distinct and parallel to the lower rim. No sinus is indicated, even beneath the main cusp. Lower surface is relatively small, more dull, darker colored, and keeled. There is no basal cavity.

Remarks.—In the absence of a basal cavity, this species illustrates a tendency of Triassic conodonts.

Occurrence.—Lower Triassic cephalopod bed, T42N, R69E; Dinner Springs Canyon, about 1½ miles east of Crittenden Ranch, 18 miles north of Montello, Elko County, Nevada.

Types.—Holotype, SUI 2278 (Pl. 96, fig. 17); unfigured paratype, SUI 2279.

Genus LONCHODINA Ulrich & Bassler, 1925

In its present usage this genus includes heterogeneous forms and needs redefinition. Such a revision must be based on more abundant material than is available from the Nevada Triassic. In any case, the pattern of the forms under consideration is so close to some older representatives of *Lonchodina* that it seems impossible to distinguish generic subdivisions within this group, which are limited to the Triassic. The reason for citing this genus under the date 1925 is given under remarks on Hibbardellidae.

LONCHODINA NEVADENSIS Müller, n. sp. Pl. 96, fig. 7

Axis strongly arched and U-shaped. Lateral limbs stout, short, somewhat tapering toward the ends, and with one limb strongly curved inward. Denticles large, discrete, regularly decreasing in size toward the ends of branches, and somewhat bowed inward. Main cusp subcentral, more than twice as large as the largest denticle. The contact between upper and lower surface is distinct. Near the main cusp the darker colored lower surface occupies more than half the height of the branches. This lower surface thins toward the ends of the limbs, and it shows fine growth lines. Its lower limit is keeled and rectangular. No basal cavity or pit is present.

Occurrence.—Lower Triassic cephalopod bed, T42N, R69E; Dinner Springs Canyon, about 1½ miles east of Crittenden Ranch, 18 miles north of Montello, Elko County, Nevada.

Types.—Holotype, SUI 2280 (Pl. 96, fig. 7); unfigured paratypes, SUI 2281.

LONCHODINA AEQUIARCUATA Müller, n. sp. Pl. 96, fig. 9

Axis very strongly arched, V-shaped, and nearly symmetric. Lateral limbs extremely long and narrow, twisted outward about 45°

near the ends. Main cusp central, small, and not very distinct from the denticles. Denticles discrete, regular, numerous, and rounded or somewhat compressed laterally in cross section. The lower surface is slightly enlarged beneath the main cusp but is otherwise not apparent.

Occurrence.—Lower Triassic cephalopod bed, T42N, R69E; Dinner Springs Canyon, about 1½ miles east of Crittenden Ranch, 18 miles north of Montello, Elko County, Nevada.

Holotype.—SUI 2282 (Pl. 96, fig. 9).

LONCHODINA TRIASSICA
Müller, n. sp.
Pl. 96, fig. 10

Axis only very little arched and bowed. Lateral limbs relatively long, high, and only slightly tapered toward the ends; one is twisted outward a very little. Main cusp which is relatively small stands a little inside the row of denticles and is nearly circular in its cross section. Denticles discrete, large, and with subcircular cross sections. With exception of the outermost, which is very small, all denticles have approximately the same size. Main cusp, as well as denticles, are strongly and somewhat irregularly bowed inwardly and posteriorly. The lower surface is darker colored, keeled, and occupies about one-third of the height of the limbs. The contact between lower and upper surface is distinct and forms a sinus below the main cusp. There is no basal pit or groove.

Occurrence.—Lower Triassic cephalopod bed, T42N, R69E; Dinner Springs Canyon, about 1½ miles east of Crittenden Ranch, 18 miles north of Montello, Elko County, Nevada.

Types.—Holotype, SUI 2283 (Pl. 96, fig. 10); unfigured paratype, SUI 2284.

Genus LONCHODUS Pander, 1856

Fragments of bars with large discrete denticles, which belong in different form-genera, are described under this name. Therefore the genus has no stratigraphic or true taxonomic significance.

LONCHODUS sp.
Pl. 96, fig. 8

The present specimen is not a part of any of the other forms described in this report. It is figured to demonstrate the very well developed basal part, which occupies more than half the height of the bar.

Occurrence.—Lower Triassic cephalopod bed, T42N, R69E; Dinner Springs Canyon, about 1½ miles east of Crittenden Ranch, 18 miles north of Montello, Elko County, Nevada.

Figured specimen.—SUI 2285 (Pl. 96, fig. 8).

Genus NEOPRIONIODUS Rhodes & Müller, 1956

This genus is well represented with 3 or 4 species in the fauna. Although there is no obvious close similarity or relationship between these species, all lack a basal cavity ("Pulpe" of Pander) or have only a very small one. In Ordovician and Silurian representatives of this genus the basal cavity is very large. In those of the Upper Devonian it is considerably smaller. However, only large Devonian specimens have a reduced basal cavity comparable to the normal forms from the Triassic. It seems that the same tendency of a reduction in basal cavity is recognizable in the Pennsylvanian also. Other groups, *e.g.*, *Trichognathus-Hibbardella*, illustrate the same reduction in a more accelerated fashion.

NEOPRIONIODUS BICUSPIDATUS
Müller, n. sp.
Pl. 95, fig. 14–17

Axis straight or very little arched. Main cusp small, rounded in its cross section, and inclined anteriorly. Particularly in the anterior part, a well developed lateral furrow divides a flared apron from the main cusp. The limb is relatively long and high. It bears numerous large, high, closely spaced, and partly fused denticles. The first of these stands closely adjacent and is nearly as high as the main cusp. The lower surface is nearly flat and shows a slot-like basal furrow which is located beneath the middle of the cusp and limb.

Remarks.—This species can be distinguished from *N. bransoni* Müller, n. sp., by a larger number of more closely spaced denticles, the first of which is nearly as high as the main cusp.

Occurrence.—Lower Triassic cephalopod bed, T42N, R69E; Dinner Springs Canyon,

about 1½ miles east of Crittenden Ranch, 18 miles north of Montello, Elko County, Nevada.

Types.—Holotype, SUI 2286 (Pl. 95, fig. 15); figured paratypes, SUI 2287, 2288 (Pl. 95, fig. 14,16,17); unfigured paratypes, SUI 2289.

NEOPRIONIODUS UNICORNIS
Müller, n. sp.
Pl. 95, fig. 18

Axis strongly arched. Main cusp very large and larger than the remainder of the unit. The main cusp is inclined anteriorly, somewhat twisted and bowed inward, and laterally compressed, with the outer side flatter than the inner one. Anterior margin of the main cusp is concave and sharper than the convex posterior. There is no apron. Posterior limb short, laterally compressed, bowed outward, and slightly twisted. It bears only three large discrete denticles. There is no gap between main cusp and first denticle. The lower surface is distinguished by a darker color and a more dull surface. It converges toward a sharp keel which consists of two lobes, meeting in the middle beneath the main cusp. The contact between lower and upper surface forms a prominent sinus which coincides with the arch of the axis. There is no basal groove or cavity. An extension of the darker colored material of the lower surface is present under the translucent surface in the middle of the main cusp.

Occurrence.—Lower Triassic cephalopod bed, T42N, R69E; Dinner Springs Canyon, about 1½ miles east of Crittenden Ranch, 18 miles north of Montello, Elko County, Nevada.

Holotype.—SUI 2290 (Pl. 95, fig. 18).

NEOPRIONIODUS BRANSONI
Müller, n. sp.
Pl. 95, fig. 19–21

Axis arched and somewhat bowed inwardly. Main cusp relatively small, pointed, inclined anteriorly, and laterally compressed but rounded anteriorly. On the lower surface it has a flared apron which apparently bears a relationship to the basal cavity of other forms. It is considerably more strongly developed on the concave (inner) side than on the outer side. There is a faint lateral furrow. The limb is long, with slightly biconvex sides. Denticles large, discrete, and pointed; they are laterally compressed and in some cases irregular in size, decreasing posteriorly. The first denticles are inclined anteriorly like the main cusp; however, the amount of obliquity decreases progressively posteriorly, and in the last third the denticles are straight, or even slightly inclined posteriorly.

The lower surface is nearly flat. With the exception of a very shallow groove, there is no basal cavity. In this feature the species differs from older apron-bearing representatives of *Neoprioniodus*, which have a well developed basal cavity.

Occurrence.—Lower Triassic cephalopod bed, T42N, R69E; Dinner Springs Canyon, about 1½ miles east of Crittenden Ranch, 18 miles north of Montello, Elko County, Nevada.

Types.—Holotype, SUI 2291 (Pl. 95, fig. 20,21); figured paratype, SUI 2292.

NEOPRIONIODUS? sp.
Pl. 95, fig. 13

Axis arched, somewhat stronger in the cusp part than in the limb. The main cusp is about as large as the limb and has a large "anticusp." The cusp is slightly directed posteriorly; its cross section is irregular-oval. Limb short, high on its front, but tapering posteriorly. There are 3–4 denticles, which progressively become smaller posteriorly; the cross section is irregular oval. Between the main cusp and the first denticle there is a gap. The lower surface is clearly distinguished from the upper surface by its darker color and shows no sinus. This lower surface is best developed on the anterior portion. The largest part is beneath the main cusp.

Remarks.—In the single representative the lower part of the main cusp is broken off. Therefore, the possibility of an anterior branch cannot be excluded. In that case, the form should be referred to *Euprioniodina*.

Occurrence.—Lower Triassic cephalopod bed, T42N, R69E; Dinner Springs Canyon, about 1½ miles east of Crittenden Ranch, 18 miles north of Montello, Elko County, Nevada.

Figured specimen.—SUI 2293 (Pl. 95, fig. 13).

Genus OZARKODINA Branson & Mehl, 1933

OZARKODINA? spp.

Pl. 95, fig. 23; Pl. 96, fig. 18

Two specimens may belong in this genus. Both have an arched denticulate bar with a single denticle of superior size approximately in the middle. The two are probably not conspecific.

Occurrence.—Lower Triassic cephalopod bed, T42N, R69E; Dinner Springs Canyon, about 1½ miles east of Crittenden Ranch, 18 miles north of Montello, Elko County, Nevada.

Figured specimens.—SUI 2294 (Pl. 95, fig. 23); SUI 2295 (Pl. 96, fig. 18).

Genus indeterminable

Pl. 95, fig. 22

This single fragmentary specimen shows a radial arrangement of relatively large denticles and a semicircular well developed lower surface. Its systematic position is not yet clear; probably it belongs to an undescribed genus.

Occurrence.—Lower Triassic cephalopod bed, T42N, R69E; Dinner Springs Canyon, about 1½ miles east of Crittenden Ranch, 18 miles north of Montello, Elko County, Nevada.

Figured specimen.—SUI 2296 (Pl. 95, fig. 22).

REFERENCES

BASSLER, R. S., 1925, Classification and stratigraphic use of the conodonts: Geol. Soc. Amer., Bull., vol. 36, p. 218–220 (abstract).

BRANSON, E. B., & BRANSON, C. C., 1947, Lower Silurian conodonts from Kentucky: Jour. Paleont., vol. 21, p. 549–556, pl. 81, 82, 1 text-fig.

——, & MEHL, M. G., 1933a, Conodonts from the Harding sandstone of Colorado: Univ. Missouri Studies, vol. 8, no. 1, p. 19–38, 65–69, pl. 1, 2.

——, & ——, 1933b, A study of Hinde's types of conodonts preserved in the British Museum: ibid., no. 2, p. 133–156, 165–167, pl. 11, 12.

——, & ——, 1941a, A record of typical American conodont genera in various parts of Europe: Denison Univ. Bull., vol. 40, no. 14, Jour. Sci. Lab., vol. 35, art. 7, p. 189–194, pl. 7.

——, & ——, 1941b, The recognition and interpretation of mixed conodont faunas: ibid., art. 8, p. 195–209.

——, & ——, 1944, Conodonts; *in* Index fossils of North America, by Shimer, H. W., & Shrock, R. R., p. 235–246, pl. 93, 94.

——, & ——, 1948, Conodont homonyms and names to replace them: Jour. Paleont., vol. 22, p. 527–528.

CLARK, D. L., & STOKES, W. L., 1956, Preliminary survey of Triassic rocks in the eastern Great Basin: Amer. Assoc. Petrol. Geol., Bull., in press.

EICHER, D. B., 1946, Conodonts from the Triassic of Sinai (Egypt): Amer. Assoc. Petrol. Geol., Bull., vol. 30, p. 613–616.

——, 1947, Micropaleontology of the Triassic of north Sinai: Bull. Inst. Egypte, vol. 28, p. 87–92.

ELLISON, S. P., 1941, Revision of the Pennsylvanian conodonts: Jour. Paleont., vol. 15, p. 107–143, pl. 20–23, 4 text-fig.

FAY, R. O., 1952, Catalogue of conodonts: Univ. Kansas Paleontological Contr., Vertebrata, art. 3, 206 p., 109 fig.

GROSS, W., 1954, Zur Conodonten-Frage: Senckenbergiana lethaea, vol. 35, p. 73–85, pl. 1–5.

HASS, W. H., 1953, Conodonts of the Barnett formation of Texas: U. S. Geol. Surv., Prof. Paper 243-F, p. 69–94, pl. 14–16.

LINDSTRÖM, M., 1954, Conodonts from the lowermost Ordovician strata of south-central Sweden: Geol. Fören. Förhandl., vol. 76, p. 517–604, pl. 1–10, 6 text-fig.

PANDER, C. H., 1856, Monographie der fossilen Fische des silurischen Systems der russisch-baltischen Gouvernements: St. Petersburg; 91 p., 8 pl.

RHODES, F. H. T., 1953, Some British lower Palaeozoic conodont faunas: Roy. Soc. London, Phil. Trans., ser. B, vol. 237, p. 261–334, pl. 20–23, 20 text-fig.

——, & MÜLLER, K. J., 1956, The conodont genus *Prioniodus* and related forms: Jour. Paleont., vol. 30, p. 695–699.

SANNEMANN, D., 1955, Oberdevonische Conodonten (to IIα): Senckenbergiana lethaea, vol. 36, p. 123–156, pl. 1–6, 4 text-fig.

ULRICH, E. O., & BASSLER, R. S., 1926, A classification of the toothlike fossils, conodonts, with descriptions of American Devonian and Mississippian species: U. S. Nat. Mus., Proc., vol. 68, art. 12, p. 1–63, pl. 1–11.

YOUNGQUIST, W. L., 1945, Upper Devonian conodonts from the Independence shale (?) of Iowa: Jour. Paleont., vol. 19, p. 355–367, pl. 54–56.

——, 1952, Triassic conodonts from southeastern Idaho: Jour. Paleont., vol. 26, p. 650–655.

——, HAWLEY, R. W., & MILLER, A. K., 1951, Phosphoria conodonts from southeastern Idaho: Jour. Paleont., vol. 25, p. 356–364, pl. 54.

——, HIBBARD, R. R., & REIMANN, I. G., 1948, Additions to the Devonian conodont faunas of western New York: Jour. Paleont., vol. 22, p. 48–59, pl. 14, 15.

JOURNAL OF PALEONTOLOGY, VOL. 30, NO. 4, P. 831–864, 7 TEXT-FIG., JULY 1956

UPPER PENNSYLVANIAN ARENACEOUS FORAMINIFERA FROM KANSAS

H. A. IRELAND
University of Kansas, Lawrence

ABSTRACT—Several thousand arenaceous Foraminifera have been derived from insoluble residues of limestones in the Shawnee and Wabaunsee groups of the Virgilian series. From these 50 species and 16 genera have been identified, of which 2 genera and 26 species are new. Many forms have been found in central Texas previously, but nearly all of the Kansas forms are much smaller in size.

Solution of the limestone destroyed the calcareous forms but the liberation of clean, unweathered, well-preserved specimens offsets the loss of forms which probably could not be extracted. Forms found in shale are likely to be somewhat imperfect due to weathering, solution, alteration or damage in extraction; especially thin, long, or tubular forms and delicate spherical forms.

The collection shows the difference between *Tolypammina* and *Ammovertella*, for a large number of perfect specimens and hundreds of well-preserved fragments were available for study. Many species of *Ammobaculites* formerly transferred to the calcareous genus *Endothyranella* are restored to their true classification as arenaceous forms, based on evidence from the Kansas samples. The evolutionary relationships of *Ammodiscus* and *Ammovertella* are shown by attached forms of the new genus *Ammodiscella*, and by gradations among the large numbers of *Ammovertella* studied. Specimens of what are probably the earliest *Astrorhiza* and the earliest *Vernueilina* are described. The species show such a large stratigraphic range that none can be considered as index fossils for subdivision of the Virgilian, but the assemblages are more distinctive. The insoluble residues show that even the pure limestones in the Virgilian have an ample supply of quartz silt to provide material for agglutinization into tests. Foraminifera appear to favor the environment of a regressive unit of a cyclothem, but have a tolerance for the deeper water environment marked by an abundance of fusulinids. There is also a relation to the cyclothem sequences in the megacycles of the Upper Pennsylvanian of Kansas.

INTRODUCTION

STUDY of Upper Pennsylvanian Foraminifera in North America has largely been confined to beds in Michigan, Texas, and southern Oklahoma. The literature on Pennsylvanian forms is sparse and from a relatively small group of workers, chiefly H. B. Brady, Cushman, Waters, Galloway, Harlton, Ryniker, Warthin, and Plummer. Little or no work has been published for the last 20 years.

The study of the insoluble residues of the Shawnee and Wabaunsee groups of the Virgilian revealed a large quantity of arenaceous Foraminifera. The forms are so abundant in some beds that they comprise 1–3 percent of the limestone or almost all of the residue. In some samples *Ammovertella*, *Tolypammina*, or *Ammodiscus* comprise 50 to 80 percent of the foraminiferal remains. About half of the species have been described previously. Of the 16 genera and 50 species found, 2 new genera and 26 new species are described.

The author is indebted to the University of Kansas for research funds to assist in this work. H. C. Perkins and Leon Wahrhaftig, while graduate students, sampled the beds, prepared and described the residues. Barbara Conkin made a preliminary examination of the insoluble residues and called attention to the samples in which Foraminifera were present. The work of these students is greatly appreciated.

All of the limestone beds of the Shawnee and Wabaunsee groups up to the base of the Permian were measured and carefully sampled (generally at 6-inch intervals). After use of the samples for a sedimentological study of the insoluble residues, the writer used the carefully prepared samples for the study of the Foraminifera. Where an original sample indicated a good representation of forms, additional material was dis-

solved for a larger quantity of foraminifers. Altogether about 2,200 specimens were selected from the thousands available in about 800 samples from 30 limestone beds. Samples were collected from two localities for each bed.

The illustrations of the Foraminifera were drawn by stippling on a photograph. The photo image was then bleached.

PREPARATION OF SAMPLES

Preparation of the acid residues was essentially the same as that used for general purposes but with special restrictions and techniques. Weak acid was used and all the fine constituents were saved. Residues made with 25 percent hydrochloric acid generally contained only fragments of Foraminifera because the effervescence was sufficiently violent to cause breakage. Consequently, acid of less than 10 percent concentration was used. Iron oxide coating on many forms obscured details and boiling in hydrochloric acid was necessary; this had to be controlled carefully because convections due to boiling also destroyed specimens. Decanting of the precipitates and separation of the clay particles required care because hollow forms were bouyant and could be floated away. Filtering eliminated most of the acid and two or three washings with water cleaned the residue. At first many excellent specimens were lost in the drying process because very fragile forms adhered to the filter paper or to the side of the beaker and were ruptured when touched. It was found that a final wash with distilled water and then alcohol allowed a rapid evaporation leaving each delicate specimen free, clean, and whole.

The solution of limestone for the recovery of arenaceous Foraminifera is an important technique. Fragile, entire forms can be obtained which are clean and unweathered. Forms collected from weathered limestone or shale are likely to be dirty, corroded, replaced, or disaggregated; and those in unweathered shales are commonly damaged in extraction. This frailty is particularly true of long tubular fragile forms such as *Tolypammina*, inflated forms like *Thurammina* and thin flat ones like many *Ammovertella*.

Solution obviously destroys many calcareous fossils associated. It also destroys the object of attachment, if such is a shell fragment or calcareous pellet. However, the clean well-developed specimens obtained by acid treatment offset some of the loss of data. Calcareous forms in adjacent shale or weathered limestone strata will furnish additional material, though imperfect, to complete the faunal collection. The study of weathered forms in shale can be augmented by using the perfect or undamaged specimens obtained by solution of associated limestones. Questions concerning the object of attachment which was dissolved by acid can be answered by studying the arenaceous forms found intact in the adjacent shales.

It is known that both calcareous and arenaceous foraminifers are present in the shale members of the Virgilian. They may be secured from many of the exposures of fresh shale, which must then be disaggregated. However, the foraminifers in the limestone are embedded and obscured by the matrix and are not available except from insoluble residues. Weathering of the limestone destroys the calcareous forms and frees the arenaceous ones which are mixed with fallen detritus; many of the forms are so fragile that they are destroyed.

The insoluble residues and the associated Foraminifera are generally less than 1 or 2 percent of the sample. In all cases there has been abundant quartz silt grains, ample to supply the needs of arenaceous foraminifers for their tests—even the purest limestones contained silt. Most of the grains in a test are fine silt, and many foraminifers have tubes or chambers whose diameters are less than 0.02 mm. with silt 0.062 to 0.004 mm. in size.

COLLECTION OF SAMPLES

The localities from which the samples were collected are shown on Text-figure 1. Collection numbers preceded by A came from a northern line of sections, essentially along the Kansas River valley, and those marked B came from a line 10 to 30 miles to the south. The same number is used for equivalent beds in A and B sections. The detailed location of each point of collection is listed below.

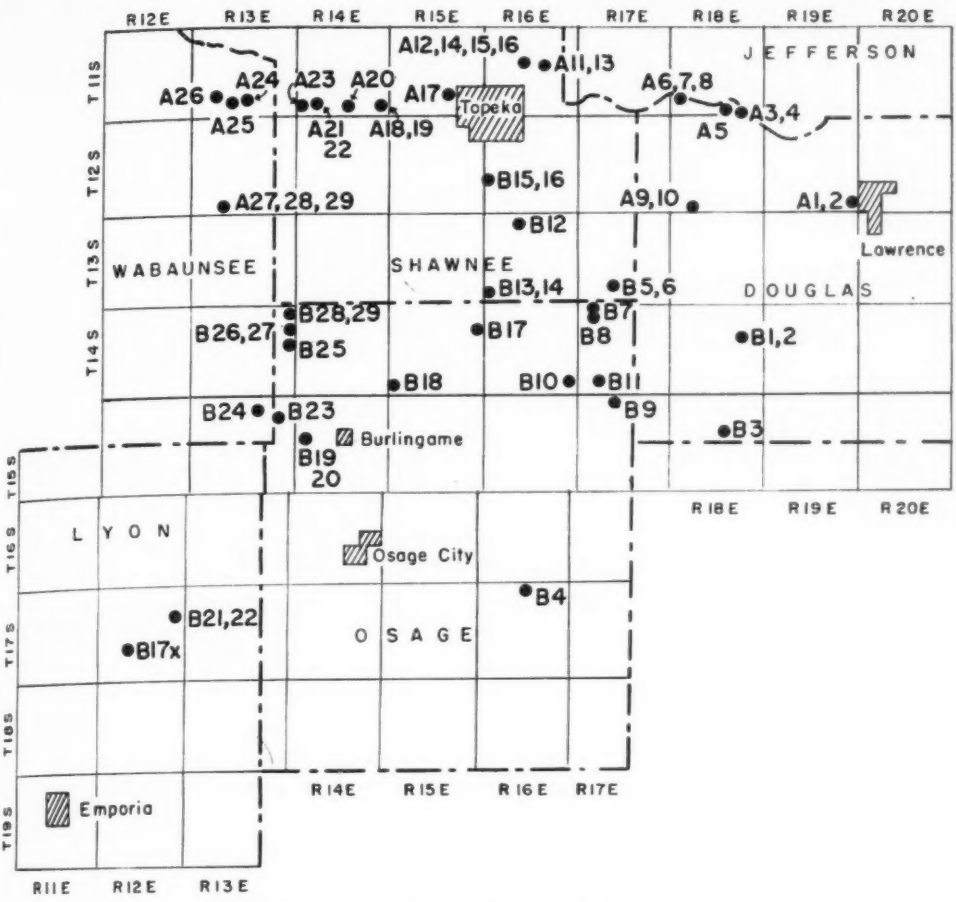
LIST OF LOCATIONS OF COLLECTIONS

Section A

Shawnee group

Oread limestone

A1. Toronto member. NW sec. 36, T. 12 S.,



TEXT-FIG. *1*—Map showing locations of collections.

R. 19 E. Roadcut on West Ninth Street, Lawrence.

A2. Leavenworth member. Same as above.

A3. Plattsmouth member. NW SW sec. 35, T. 11 S., R. 18 E. Quarry along railroad at northeast edge of Lecompton.

A4. Kereford member. Same as A3.

Lecompton limestone

A5. Spring Branch member. CSL sec. 34, T. 11 S., R. 18 E. Roadside at west edge of Lecompton.

A6. Big Springs member. NEC sec. 31, T. 11 S., R. 18 E. Roadside about one-quarter mile south of Santa Fe railroad.

A7. Beil member. Same as A6.

A8. Avoca member. Same as A6.

Deer Creek limestone

A9, Ozawkie member. CNL sec. 32, T. 12 S., R. 18 E. Roadside south of U. S. Highway 40.

A10. Rock Bluff member. Same as A9.

A11. Ervine Creek Member. SE sec. 15, T. 11 S., R. 16 E. Calhoun Bluffs, north of creek bridge 1¼ miles east of U. S. 40-75 cloverleaf to Topeka.

Topeka limestone

A12. Hartford member. CN¼ sec. 16, T. 11 S., R. 16 E. One-half mile north on side road 1 mile east of U. S. 40-75 cloverleaf to Topeka.

A13. Curzon member. Same as A11.

A14. Sheldon member. Same as A12.

A15. Du Bois member. Same as A12.

A16. Coal Creek member. Same as A12.

Wabaunsee group

A17. Church and Utopia members of Howard limestone. NE sec. 27, T. 11 S., R. 15 E. Railroad cut along Kansas River.

A18. Rulo limestone, NE sec. 36, T. 11 S., R. 14 E. Highway cut and creek on K-10.

A19. Burlingame limestone. Same as above.
A20. Wakarusa limestone. NW Sec. 34, T. 11 S., R. 14. E. Highway cut on K-10.
A21. Reading limestone. NW sec. 31, T. 11 S., R. 14 E. Roadcut on Highway K-10.
A22. Elmont limestone. Same as above.
A23. Tarkio limestone. NW cor. sec. 32, T. 11 S., R. 14 E. Roadcut on K-10.
A24. Maple Hill limestone. CSL sec. 27, T. 11 S., R. 13 E. Roadcut on K-10.
A25. Dover limestone. NW sec. 33, T. 11 S., R. 13 E. Roadcut on K-10.
A26. Grandhaven limestone. CSL sec. 29, T. 11 S., R. 13 E. Roadcut on K-10.
A27. Jim Creek limestone, CWL sec. 33, T. 12 S., R. 13 E. Roadcut on section line.
A28. Caneyville limestone. Same as above.
A29. Brownville limestone. Same as above.

Section B

Shawnee group

Oread limestone

B1. Toronto member. CN¼ sec. 14, T. 14 N., R. 18 E. Northeast side of Lone Star Lake.
B2. Leavenworth member. Same as above.
B3. Plattsmouth member. SW NE sec. 15, T. 15 S., R. 18 E. Roadside north of house, 2 miles south of U. S. Highway 50.
B4. Kereford member. NE sec. 3, T. 18 S., R. 16 E. Roadside south of Marais des Cygnes River north of Melvern.

Lecompton limestone

B5. Spring Branch member. NEC sec. 33, T. 13 S., R. 17 E. Roadside at southeast edge of town of Richland.
B6. Big Spring member. Same as B5.
B7. Beil member. NWC sec. 5, T. 14 S., R. 17 E. At bend of road where railroad crosses.
B8. Avoca member. SWC sec. 5, about a mile south of B7.

Deer Creek limestone

B9. Ozawkie member. CNL sec. 4, T. 15 S., R. 17 E. Roadside south of U. S. Highway 50, about 1½ miles east of Overbrook.
B10. Rock Bluff member. Sec. 36, T. 14 S., R. 16 E. Along railroad south of section line road.
B11. Ervine Creek member. CNL sec. 32, T. 14 S., R. 17 E. South side of section line road, 1 mile north and ½-mile east from Overbrook.

Topeka limestone

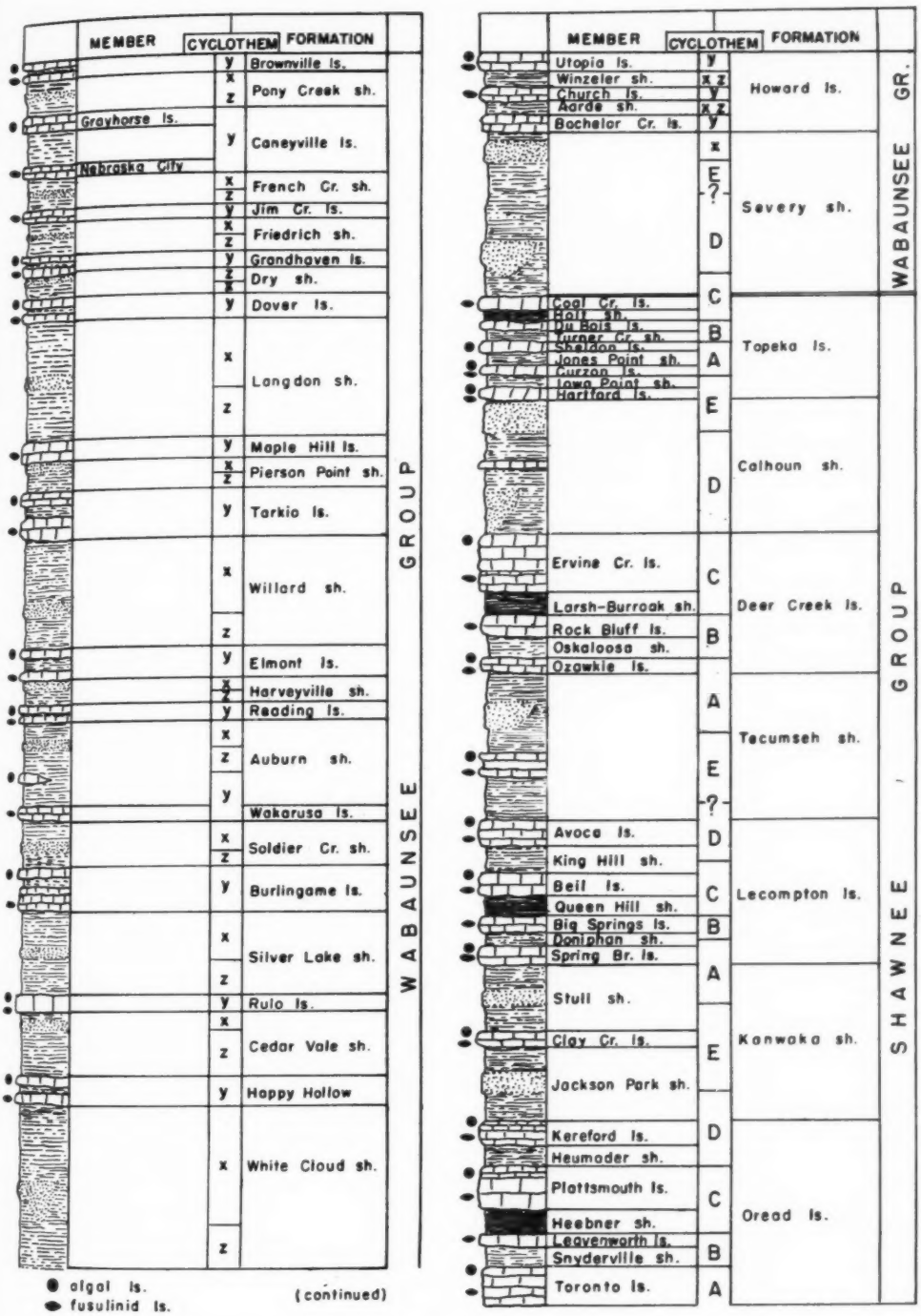
B12. Hartford member. SWC sec. 4, T. 13 S., R. 16 E. Along stream.
B13. Curzon member. SWC sec 31, T. 13 S., R. 16 E. Along U. S. Highway 75, 1½ miles south of Wakarusa Creek.
B14. Sheldon member. Same as B13.
B15. Du Bois member. CSL sec. 19, T. 12 S., R. 16 E. Roadside ½ mile east of U. S. Highway 75 and railroad overpass.
B16. Coal Creek member. Same as B15.

Wabaunsee group

B17. Church and Utopia members of Howard limestone. SE SE sec. 12, T. 14 S., R. 15 E. Along U. S. Highway 75, north of section line.
B17x. Happy Hollow limestone. SW sec. 21, T. 17 S., R. 12 E. Along creek west of the road.
B18. Rulo limestone. NW sec. 31, T. 14 S., R. 15 E.
B19. Burlingame limestone. NE sec. 18, T. 15 S., R. 14 E. Along west side of section road ½ mile south of Highway K-31.
B20. Wakarusa limestone. Same as above.
B21. Reading limestone. Sec. 12, T. 17 S., R. 12 E. Along U. S. Highway 50.
B22. Elmont limestone. Same as above.
B23. Tarkio limestone. Sec. 12, T. 15 S., R. 13 E. Roadside east of north-south road.
B24. Maple Hill limestone. SW SE sec. 2, T. 15 S., R. 13 E. Roadside on north side of section line road.
B25. Dover limestone. SW SE sec. 13, T. 14 S., R. 13 E. Along creek across east-west section line road.
B26. Grandhaven limestone. CEL sec. 12, T. 14 S., R. 13 E.
B27. Jim Creek limestone. Same as above.
B28. Caneyville limestone. CEL sec. 1, T. 14 S., R. 13 E.
B29. Brownville limestone. Same as above.

STRATIGRAPHY

The stratigraphic succession of Shawnee and Wabaunsee groups of the Upper Pennsylvanian in eastern Kansas is given in Text-figure 2. Each stratum is part of a cyclothem which is lettered in the designated column. A sequence of cyclothems makes a megacycle which includes cyclothems A–E in the Shawnee group; and they are named for the principle limestone formation included in the sequence. As an example, the Oread megacycle includes beds from the upper part of the Lawrence shale, the Oread limestone, and part of the Kanwaka shale. Cyclothems and megacycles are not subdivided according to formational boundaries, but according to lithology, environment of deposition, and fossil content. Consequently, the Toronto cyclothem A of the Oread megacycle extends down into the Lawrence shale and across a major boundary into the Douglas group. Similarly, cyclothems C, D, and E of the Topeka mega-



TEXT-FIG. 2—Stratigraphic column of Upper Pennsylvanian in eastern Kansas.

cycle extend upward into the Wabaunsee group. One of the prominent digressions from formational boundaries is the position of the Hartford limestone member as part of the E cyclothem, though it is part of the Topeka formation. One principle characteristic of cyclothems is a well-developed fusulinid limestone and an algal limestone near the center, which are indicated by symbols.

Cyclothems in the Wabaunsee group are much the same as in the Shawnee group but they are not as well-developed, though they are well marked by the limestone beds. In most cases the fusulinid and algal units are separated by several inches to many feet of shale. Transgressive shale units are below the fusulinid limestone and regressive shale units are above the algal bed, grading into nonmarine beds. The Wabaunsee cyclothems are indicated by x, y, and z on Text-figure 2 to show the equivalent beds in each megacycle.

The units of an ideal cyclothem and a megacycle in Kansas have been described by Moore (1936). In no case is the ideal found in any one sequence, but each unit is found in one sequence or another, and nearly every cyclothem has the middle fusulinid limestone.

DISCUSSION ON THE FAUNA

The distribution and frequency of the Foraminifera by species and by location is shown in Table 1. The following order is the rank of the principal genera in abundance of specimens: *Ammovertella*, *Tolypammina*, *Ammodiscus*, *Glomospira*, *Textularia*, *Ammobaculites*, *Ammodiscella*, *Bigenerina*. These include 80 percent of all the specimens secured. The first four in rank are all from the family of Ammodiscidae and represent 75 percent of all the forms mounted.

RELATION TO CYCLOTHEMS

The quantity and variety of genera in relation to the cyclothems gives some information of the environment of the arenaceous Foraminifera in the Shawnee megacycles. These fossils are most abundant in the algal limestones of the regressive cycle. The algal or "super" limestone lies above the middle limestone containing fusulinids found at the maximum transgression of the sea during a cyclothem, and may be in the upper part of it or be separated by a shale.

The "super" limestone is generally characterized by oolites, algae, and a few molluscoids and molluscans embedded in flaggy, silty, or granular limestone. The algal limestone is generally absent in the B cyclothem and the lack of abundant foraminifers in that cycle indicates that preference is for the shallower water environment of the regressive sea. However, beds containing fusulinids also have abundant arenaceous Foraminifera, indicating that tolerance for deeper water is broad. It may be that the arenaceous forms are more numerous in the regressive phase because more silt was available for the tests.

The cyclothemic units of megacycles show a suggestion of correlation between equivalent units (Text-fig. 2, Table 1). Three of the A cyclothems of the four Shawnee megacycles have an abundance of forms and good representation of genera, but the fourth (Spring Branch of the Lecompton megacycle) has few forms. All of the B cyclothems show a small number of forms and genera, and even the otherwise ubiquitous *Ammovertella* are uncommon; *Tolypammina* are not abundant and *Ammodiscus* are absent. These units include the Leavenworth, Big Springs, Rock Bluff, and Du Bois limestones, The C cyclothems have no basis for correlation. The Plattsmouth has few genera but contains abundant *Tolypammina;* the Beil has chiefly *Ammovertella* and *Tolypammina;* the Ervine Creek has abundant *Ammodiscus* and *Glomospira* and a few representations of most other genera; the Coal Creek is restricted to four genera, all abundant and all from the family Ammodiscidae. The Coal Creek fauna is well preserved, and has the most restricted but consistent assemblage of all beds studied. Beds of the cyclothem D have a fair representation of most genera.

Cyclothem D in this area has no limestone in two of the megacycles but in the other two, most genera have a fair representation. The Hartford in cyclothem E is marked by *Bigenerina* and *Thurammina* in addition to the almost ever-present *Ammodiscus*, *Ammovertella*, and *Tolypammina*.

STRATIGRAPHIC DISTRIBUTION

The stratigraphic range of all but a few of the species found in Kansas includes

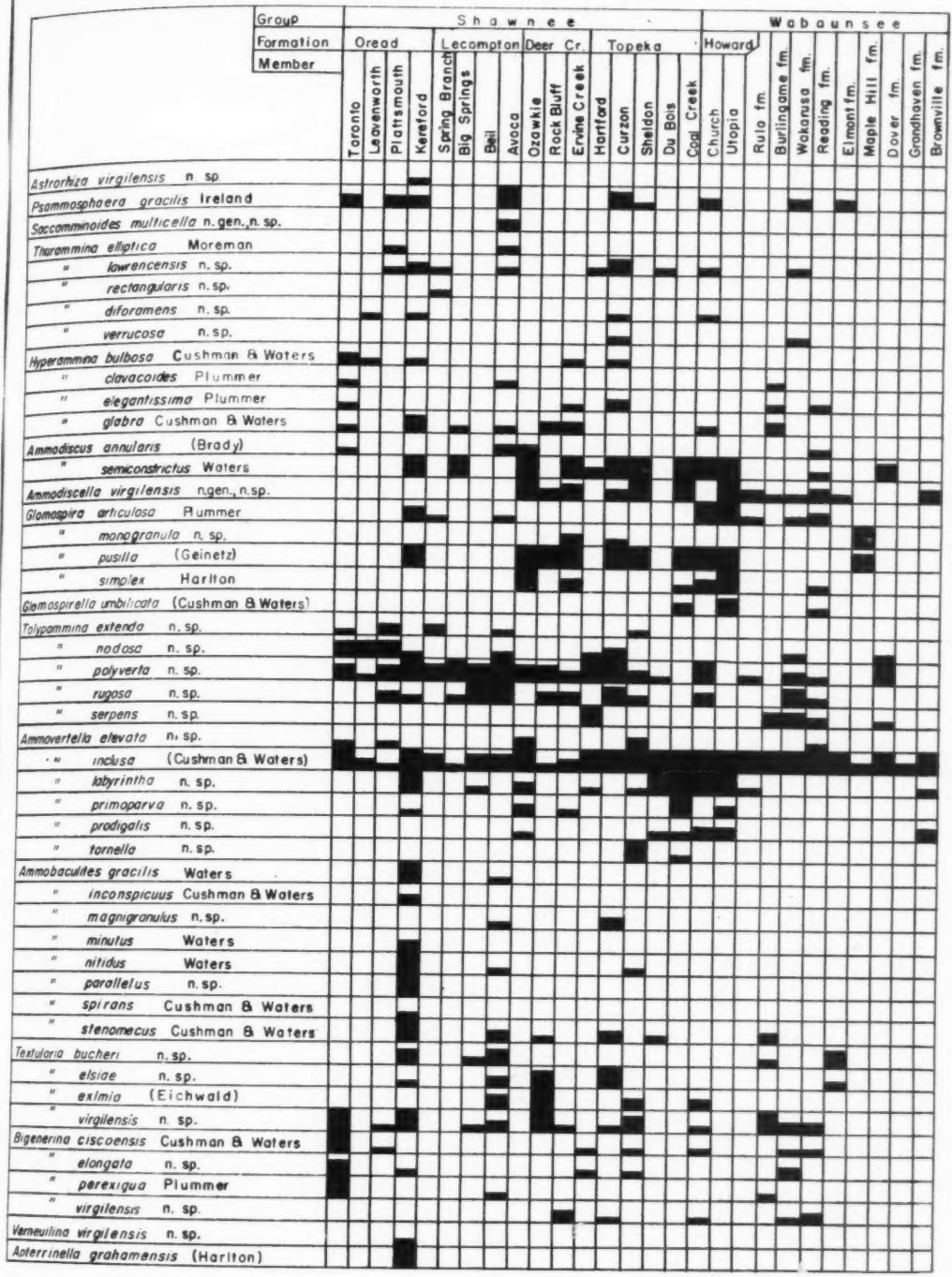


TABLE 1—DISTRIBUTION OF VIRGILIAN ARENACEOUS FORAMINIFERA

nearly all of the Shawnee and Wabaunsee groups. It is very difficult to select any species which is so limited that it will identify a formation. The most significant observation is that the Upper Pennsylvanian beds are characterized by a large quantity of *Ammodiscus, Ammovertella, and Tolypammina.* Generally *Glomospira* are very abundant in beds where they occur, but they are absent in about half of the beds studied. All of these genera are in the family Ammodiscidae.

Abundant *Ammobaculites* is a fairly good marker for the Kereford member of the Oread limestone, but it is also found in small numbers in a few higher beds. From the evidence in our collections, *Ammobaculites* almost disappears above the Oread formation and it certainly disappears above the Burlingame, for the three specimens there are the only record for the entire Wabaunsee group. The Kereford has 85 percent of all the *Ammobaculites* found.

Bigenerina has a distribution similar to the *Ammobaculites.* It is abundant in the Toronto member of the Oread, less common in higher beds, and is absent above the Reading limestone in the Wabaunsee group. The Toronto has 65 percent of all the *Bigenerina* found.

Textularia are found in over half of the beds studied, but no species have diagnostic value for individual formations or groups. They are found in at least one member of each formation of the Shawnee group, but none occur in the upper part of the Wabaunsee above the Elmont limestone.

Primitive forms previously recognized in Silurian beds continue into the Pennsylvanian. The genera *Psammosphaera* and *Thurammina* are represented in both systems.

The recognition of *Verneuilina* in the Virgilian provides the oldest known occurrence, previously the Jurassic. Also the form called *Astrorhiza*, if correctly identified, is the oldest known form of that genus.

Members of the Oread formation have fairly distinct characteristics. The Toronto limestone has abundant *Bigenerina* and *Textularia* and no *Ammobaculites* or *Glomospira*. The Leavenworth is marked by almost a complete lack of Foraminifera, and the Plattsmouth has abundant *Tolypammina* but little else. The Kereford member has abundant or common species of nearly all genera found, except *Bigenerina*. Segregation of the Oread limestone as a unit can be based on the abundant *Ammobaculites, Textularia,* and *Bigenerina.*

Relation of *Tolypammina* and *Ammovertella*

One of the results of this study has been the determination of significant differences between *Tolypammina* and *Ammovertella*, not adequately differentiated in past publications. Hundreds of specimens were available for this study. The significant differences are in the cross-section of the tube, the presence or absence of an agglutinated bottom wall where attached, and the coiling or bending in the initial stage. It is important to have these characteristics known because the two genera commonly occur together; most of the specimens recovered are fragments of the tubes and difficult to recognize separately.

The test of a *Tolypammina* is generally a free tube circular in cross-section and attached only in the initial stage and at various points in the later stage where support of the long tube is needed (Text-fig. 4–31b, 32). Growth of the tube is always in random directions. The lower wall of the tube, where attached, is generally of agglutinated particles, though in some cases the surface of the object of attachment is used as part of the lower wall. The initial stage may be straight, slightly coiled, or with one or two whorls.

Ammovertella is generally attached throughout the length of the tube, but the terminal portion may be unattached and circular in outline. Growth from the proloculus is sinuous, back and forth in a plane with the test generally enlarging in the same direction. In the final stage the tube may make a partial or complete encirclement of the early portion of the test (Text-fig. 5—6–14). A lower wall is not found because the surface of attachment serves as the bottom of the test; and the cross-section of the tube is semicircular, flat on the bottom and convex on top. Tubes bent back over the top of the test use the older portions of the tube as a bottom surface.

Forms of *Tolypammina* initially like *Hyperammina* (Text-fig. 4—26,31) and grading into those with *Ammodiscus* affinities (Text-fig. 4—27, 5—5) may be seen among

the large number of specimens. Other *Tolypammina* may be seen which grade into forms resembling *Ammovertella*.

The new genus *Ammodiscella* with its attached coil and other characteristics is intermediate between the unattached but coiled *Ammodiscus* and *Ammovertella*. It evolves into *Ammovertella* by loosing the planispiral coil and developing sinuous bends. Some *Ammodiscella* bear a tube extending over the test like some specimens of *Ammovertella*. *Tolypammina serpens* (Text-fig. 5—3–5) shows the coiling feature of *Ammodiscus* and also the type of sinuous bending characteristic of *Ammovertella;* however, the tubes are circular and fully agglutinated. The coiling and random direction of *Glomospira* tubes are related to *Tolypammina* and confirms their placement in the family Ammodiscinidae.

Isomorphism

My identification of specimens includes *Ammobaculites spirans* and *A. inconspicuus* Cushman & Waters; *A. nitidus*, *A. gracilis*, and *A. minutus* Waters. These species, and others not found in Kansas, had been transferred to a new genus with a calcareous test called *Endothryanella* (Galloway & Harlton; 1930). The change was based on the premise that the "*Ammobaculites*" involved have become granular during fossilization, roughened by weathering, or are a result of grains attached to the outside of a calcareous test. Those authors state that the surface of *Endothyranella* is smooth, shiny, and punctate, though rough in some cases. It is my belief that the forms described herein are not *Endothyranella* and that they should be reassigned their original generic name.

Specimens secured by solution of limestone in hydrochloric acid have tests of quartz grains with siliceous cement; they are not calcareous and therefore are not *Endothyranella*. The forms were freed so well preserved that the features and composition are well-defined and unaltered. No silicification of associated fossils had occurred, and it is known that many unsilicified calcareous forms were present in the associated strata prior to acid treatment. The species were therefore arenaceous originally and the generic name *Ammobaculites* is retained.

The work of Moreman (1930) and Ireland (1939) on Silurian arenaceous Foraminifera in the Arbuckle Mountains and the comments of Cushman (1930, 1935) show that arenaceous forms are much more primitive than calcareous ones. However, isomorphic forms with calcareous or quartzose tests may have evolved. Discussions by Waters (1927b) and by Plummer (1930) have a bearing on isomorphism of tests. The problem of parallel forms of different composition is also involved between *Ammodiscus* and *Cornuspira*, *Reophax* and *Nodosinella*, *Tolypammina* and *Apterrinella*, *Ammovertella* and *Calcitornella*, *Earlandia* and *Hyperammina*, and others. Are each of these pairs to be classified as the same genus or should they be separated because one is quartzose arenaceous and the other calcareous-arenaceous or all calcareous? Waters (1927b) points out that a genus may have calcareous granules with calcareous cement in limestone or calcareous shale where quartz grains were not available; and that quartzose arenaceous tests with siliceous cement occur in sandy shales. Both types were found by me in a 6-foot layer, proving that both calcareous and sandy shale existed there. I find that forms described by many authors from shale, with quartzose grains and siliceous cement, are also present in pure limestone. I believe that the forms with quartz particles have developed contemporaneously with calcareous forms but should be given different generic names even though they may otherwise be the same in appearance and morphology.

That a calcareous form, such as *Endothyranella*, would choose quartz silt in preference to calcite particles when both were available does not appear likely to me. The Kansas forms called *Ammobaculites* had both quartz and calcite grains available for selection, but the tests found in insoluble residues show that quartz was selected and siliceous cement was used. This discrimination by the foraminifers leads me to believe that they had distinctly different habits and that *Endothyranella* and *Ammobaculites* are different genera.

Conclusion

The insoluble residues of the Virgilian make available arenaceous Foraminifera not otherwise obtainable. The forms described are not commonly seen in shale beds

and are obscured in the limestone matrix unless samples from such beds are dissolved in acid. The forms in limestone have a greater correlative value because the limestone beds have greater lateral distribution than shales. Limestone chips from oil well samples may be treated with acid and arenaceous foraminifers recovered while most of the unweathered shale chips will resist disaggregation and require methods of extraction that prevent recovery of identifiable foraminifers. Knowledge of arenaceous Foraminifera from beds which crop out at the surface may be important to subsurface geologists because oil well drills destroy most of the megascopic fossils, unless cores are taken. Limestone cores are much more amenable to solution and recovery of foraminifers than cores of shale.

The identification of species described from Michigan, Oklahoma, and Texas extends knowledge of their distribution. The description of 2 new genera and 26 new species enlarges the knowledge of the little known Pennsylvanian forms.

Virgilian arenaceous Foraminifera seem to prefer the environment of shallower water of the regressive phase of a cyclothem because they are more abundant in the algal or "super" limestone. However, they are tolerant of the deeper water phase of the maximum transgression because they are common and even abundant in the fusulinid limestone.

Foraminifera of the family Ammodiscidae comprise 75 percent of the fauna. *Ammobaculites* and *Bigenerina* are most abundant in the lower Shawnee beds but neither is abundant where the other occurs. *Textularia* occurs throughout the stratigraphic column investigated.

Cyclothem B has few Foraminifera, probably because the algal bed is not present in it. Other cyclothems show no significant relations.

Species of Silurian *Thurammina* and *Psammosphaera* are extended in range into the Upper Pennsylvanian, *Astrorhiza* and *Verneuilina* were previously known only from younger strata.

The significant differences between *Ammovertella* and *Tolypammina* are apparent from the hundreds of specimens available. The relationship to other Ammodiscidae is also clarified.

The new genus *Ammodiscella* is an intermediate between *Ammodiscus* and *Ammovertella*.

Ammobaculites is recognized as an isomorphic equivalent of *Endothyranella*. The several species subsequently referred to *Endothyranella* are restored to their original generic assignment.

Ammovertella is recognized as the arenaceous equivalent of *Calcitornella*. An examination of the associated insoluble residues indicates that abundant quartz silt was available for arenaceous tests. The resistance to solution by acid demonstrates their selective usage of quartz particles, a generic character. Absence of any silicified fossils in the same sample rules out the probability of secondary silicification.

SYSTEMATIC PALEONTOLOGY

All type forms are deposited in the U. S. National Museum and serial numbers are included. The localities at which collections were made are given in a list (Table I). Most of the references to collection numbers will be omitted from the descriptions because such numbers can be secured from the list. If no collection number is given it may be assumed that the sample came from the "A" series of the bed mentioned.

Family ASTRORHIZIDAE Cushman, 1925

Genus ASTRORHIZA Sandahl, 1858

ASTRORHIZA VIRGILENSIS Ireland, n. sp.

Text-fig. 3—1

Test free, roughly stellate, composed of a single chamber with projections of irregular length and linear depressions that appear to divide the test into chambers; walls thin, composed of fine uniform quartz grains poorly cemented giving a fragile test; apertures single at end of each projection.

Dimensions.—Length, 0.50 mm.; width, 0.45 mm.; thickness, 0.15 mm.

Occurrence.—Near the middle of the Spring Branch member of the Lecompton limestone (Coll. B5).

Remarks.—Only one specimen was found, but it is perfectly preserved and well developed. It lacks the spherical or angular character of *Thurammina*. If identification is correct, this is the earliest *Astrorhiza* known.

Holotype.—U.S.N.M., P2029.

Family SACCAMMINIDAE Cushman, 1927
Subfamily PSAMMOSPHAERINAE Cushman, 1927
Genus PSAMMOSPHAERA Schulze, 1875
PSAMMOSPHAERA GRACILIS Ireland, 1939
Text-fig. 3—3,4

Psammosphaera gracilis IRELAND, Jour. Paleont., vol. 13, p. 194, fig. 10,11.
"Test free, spherical, very small; wall thick composed of uniform medium to fine size sand grains well cemented; surface rough; apertures not apparent."

Dimensions.—Diameter, 0.12 to 0.20 mm.

Occurrence.—A few sphecimens are found in most of the formations of the Shawnee and Wabaunsee groups. Most common in Avoca, Curzon, and Wakarusa limestones.

Remarks.—Simple spherical forms like *Psammosphaera* are difficult to separate into species. The Kansas specimens look no different than the Silurian forms described by me, except that the walls have coarser sand grains. I do not think a different specific name is justified.

Subfamily SACCAMMININAE Cushman, 1927
Genus SACCAMMINOIDES Ireland, n. gen.
Type species: *Saccamminoides multicellus*, n. sp.

Test attached with basal grains of test agglutinated to object of attachment, single chamber more or less equidimensional with several ovoid to elongate cells separated by distinct well-developed linear depressions on the top, but all connected in the interior as a single chamber; walls thin of uniform size sand cemented into a smooth surface; aperture single on the end of a pronounced neck at the plane of attachment and centrally located on the side of the end cell.

SACCAMMINOIDES MULTICELLUS Ireland, n. sp.
Text-fig. 3—2a,b

Test attached with basal grains of test agglutinated to object of attachment; single chamber more or less equidimensional with several ovoid to elongate cells separated by well-developed linear depressions on the top, but all connected in the interior into a single chamber; walls thin of uniform size sand cemented into a smooth surface; aperture single on the end of a pronounced neck at the plane of attachment and centrally located on the side of the end cell.

Dimensions.—Width, 0.62 mm.; cells, 0.28 to 0.56 mm. long, 0.12 to 0.15 mm. wide and 0.05 to 0.12 mm. high.

Occurrence.—Avoca member of Lecompton limestone in Coll. B8.

Remarks.—This unique species is rare but the type is entire and excellently preserved. Other fragments were found, but the form is very fragile.

Holotype.—U.S.N.M., P2030.

Genus THURAMMINA H. B. Brady, 1879
THURAMMINA DIFORAMENS Ireland, n. sp.
Text-fig. 3—6,7

Test free, highly inflated, spherical, two neck-like projections on opposite sides low down below center of the sphere; wall thin, fragile, with uniform size fine quartz particles well cemented; aperture on end of each projection.

Dimensions.—Holotype (Text-fig. 3—7): diameter, 0.30 mm.; fig. 6, 0.15 mm.

Occurrence.—Upper part of Wakarusa limestone in Coll. A19 and near the top of the Plattsmouth member of the Oread limestone in Coll. A3.

Remarks.—All specimens are consistent in being spherical and having only two neck-like projections each with an aperture.

Holotype.—U.S.N.M., P2033.

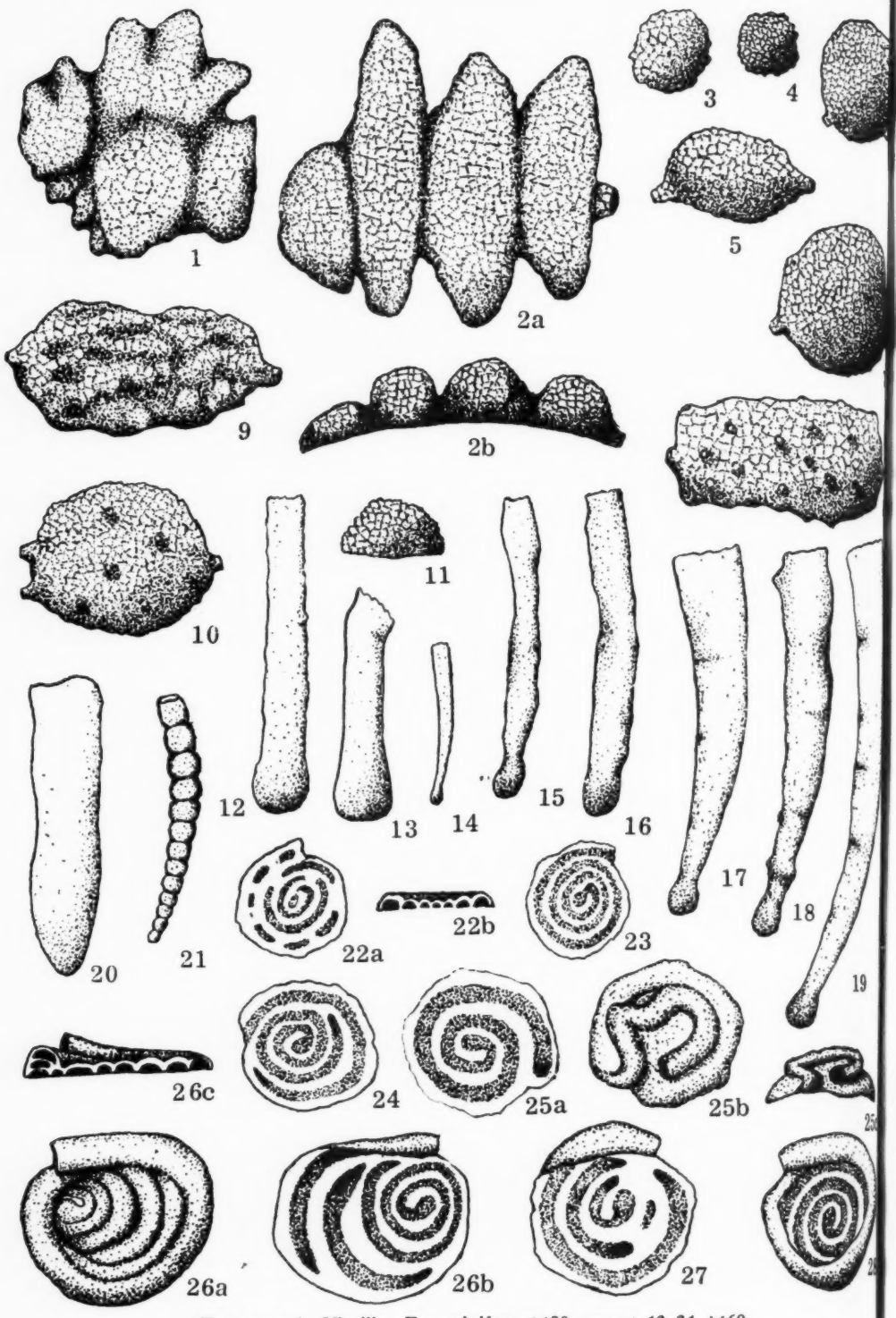
THURAMMINA ELLIPTICA Moreman, 1930
Text-fig. 3—5

Thurammina elliptica MOREMAN, 1930, Jour. Paleont., vol. 4, p. 54, pl. 5, fig. 2,4.
Test free, ellipsoidal; wall thin composed of fine sand well cemented; one aperture on each end of tube-like projection; color white.

Dimensions.—Length, 0.30 mm.; height, 0.16 mm.

Occurrence.—Plattsmouth member of Oread limestone 6 feet below top (Coll. A3), and in Avoca member of Lecompton.

Remarks.—Two specimens were found and they are almost exact duplicates of the Silurian species described by Moreman. Thus, there is little justification for coining a new specific name for the Pennsylvanian specimens.



TEXT-FIG. 3—Virgilian Foraminifera, ×80; except *12–21*, ×60.

THURAMMINA LAWRENCENSIS
Ireland, n. sp.
Text-fig. 3—10

Test free, globular or ovoid, sometimes slightly angular; walls fragile, composed of uniform-size quartz particles; surface smooth to rough with three or more randomly spaced tubercles or projections; single aperture at the end of each neck-like projection.

Dimensions.—Diameter, 0.20 to 0.40 mm. Holotype (Text-fig. 3—10): diameter, 0.38 mm.

Occurrence.—Found in the Plattsmouth and Kereford members of the Oread limestone, Spring Branch and Avoca members (holotype) of Lecompton (Colls. B5 and B8), in Hartford, Curzon, and Du Bois members of Topeka formation. Wabaunsee beds containing this species are Church and Wakarusa limestones.

Remarks.—This species has considerable variation in form. Many of the specimens are crushed and give an angular appearance. The globular shape is the most common, but somewhat angular ones are associated and do not appear to be sufficiently different to warrant description as a new species.

Holotype.—U.S.N.M., P2031.

THURAMMINA RECTANGULARIS
Ireland, n. sp.
Text-fig. 3—8

Test free, elongate with gently undulating flattened surfaces and abruptly rounded edges and corners giving a box-like appearance; wall thin of fine uniform size quartz grains well cemented; surface smooth with many protuberances; aperture at the end of each protuberance.

Dimensions.—Length, 0.52 mm.; width, 0.25 mm.

Occurrence.—Upper part of Spring Branch member of Lecompton limestone.

Holotype.—U.S.N.M., P2032.

THURAMMINA VERRUCOSA
Ireland, n. sp.
Text-figure 3—9

Test free, elongate with a neck-like projection at each end, many irregular elevations giving a papillate appearance and the suggestion of a surface covered with warts; wall thin, composed of medium size quartz grains giving a rough surface; aperture at the end of each of the two neck-like projections.

Dimensions.—Length, 0.52 mm.; width, 0.25 mm.

EXPLANATION OF TEXT-FIG. *3*

1—Astrorhiza virgilensis Ireland, n. sp. Top view.
2—Saccamminoides multicellus Ireland, n. gen., n. sp. *2a*, top view; *2b*, side view.
3,4—Psammosphaera gracilis Ireland.
5—Thurammina elliptica Moreman.
6,7—Thurammina diforamens Ireland, n. sp.
8—Thurammina rectangularis Ireland, n. sp.
9—Thurammina verrucosa Ireland, n. sp.
10—Thurammina lawrencensis Ireland, n. sp.
11—Webbinella sp. Side view.
12,13—Hyperammina bulbosa Cushman & Waters
14-16—Hyperammina elegantissima Plummer
17-19—Hyperammina glabra Cushman & Waters
20—Hyperammina clavacoidea Plummer
21—Nodosinella perelegans Plummer
22-28—Ammodiscella virgilensis Ireland, n. gen., n. sp.
22a, bottom view, planispiral form; *22b*, cross-section.
23, bottom view, planispiral form.
24, bottom view, one whorl over top.
25a, bottom view, tube bends back over test; *25b*, top view; *22c*, side view.
26a, holotype, top view, two whorls over top of test, coiling asymmetrical; *26b*, bottom view; *26c*, cross-section.
27, bottom view.
28, bottom view, last whorl overlapped edge of object of attachment.

Occurrence.—Upper part of Wakarusa limestone (Coll. A20) and from the middle part of Curzon member of the Topeka limestone (Coll. A13).

Remarks.—A very distinctive easily recognized form with no near resemblances.

Holotype.—U.S.N.M., P2034.

Subfamily WEBBINELLINAE
Cushman, 1927
Genus WEBBINELLA Rhumbler, 1903
WEBBINELLA sp.
Text-fig. 3—11

Test attached, hemispherical, object of attachment serves as bottom of test; wall thick, composed of medium size sand well cemented; surface rough; aperture a slight channel at the end of test at base of attachment, only one visible.

Dimensions.—Diameter 0.20 mm.

Occurrence.—Ervine Creek (Coll. A11).

Remarks.—This specimen appears to be *Webbinella*. Only one specimen was found and a new specific name is therefore not justified. It is included to complete the record.

Family HYPERAMMINIDAE
Eimer & Fickert, 1899
Subfamily HYPERAMMININAE
Cushman, 1910
Genus HYPERAMMINA
H. B. Brady, 1878
HYPERAMMINA BULBOSA
Cushman & Waters, 1927
Text-fig. 3—12,13

Hyperammina bulbosa CUSHMAN & WATERS, 1927, Contr. Cushman Lab. Foram. Res., vol. 3, p. 109, pl. 22, fig. 7a,b.

Test with a fairly large proloculum broader than the tubular second chamber, flattened at one side, convex on the other, the tubular chamber nearly circular in transverse section; wall arenaceous; aperture formed by the open end of the tube. Length variable, diameter of the tubular chamber 0.10 mm.

Dimensions.—Text-figure 3—12: length, 0.79 mm.; diameter of tube, 0.08 mm.; diameter of proloculus, 0.14 mm.

Occurrence.—Toronto, Leavenworth, and Kereford members of Oread limestone; Ervine Creek member of Deer Creek limestone; and Curzon member of Topeka limestone (Coll. B13).

Remarks.—Cushman & Waters found this species in Michigan (1927a) and in the Graham formation in central Texas (1930). Plummer (1945) found that it ranged from Marble Falls into the upper Strawn.

HYPERAMMINA CLAVACOIDEA
Plummer, 1944
Text-fig. 3—20

Hyperammina clavacoidea PLUMMER, 1945, Univ. Texas Pub. 4401, p. 221, pl. 15, fig. 11–14.

The large, elongate, gently bulbous initial extremity of this elongate species, which is invariably completely compressed in the Texas Pennsylvanian section, characteristically merges very gradually into the somewhat narrower tubular second chamber, which enlarges almost imperceptibly. The thin shell wall is very finely rugose with considerable cement, but in some places is almost smooth. Only a single oral extremity is known, and this is somewhat constricted and bluntly attenuate toward the terminal aperture, which was originally round but in the flattened fossil tests is an elongate silt. Length of holotype (short fragment of an initial extremity), 1.0 mm.; breadth of proloculum, 0.23 mm.; breadth of tubular chamber at end of fragments, 0.15 mm.

Dimensions.—Length, 0.75 mm. (probably broken): diameter 0.18 mm.

Occurrence.—Toronto member of Oread, Avoca member of Lecompton (Coll. B8), and Burlingame limestone.

HYPERAMMINA ELEGANTISSIMA
Plummer, 1945
Text-fig. 3—14–16

Hyperammina elegantissima PLUMMER, 1945, Univ. Texas Pub. 4401, p. 222, pl. 15, fig. 17–25.

"This slender, usually rather glossy, smooth test has a very narrowly rounded initial extremity and a straight to arcuate, gradually expanding tubular chamber, which is only rarely separated from the small megalosphere by a faint constriction. The microspheric form is finely tapering. The shell wall, composed of minute siliceous granules, is thin, so that most tests are strongly compressed or otherwise deformed, but the considerable proportion of siliceous cement makes them unusually rigid for their size. The oral extremity is somewhat constricted around a circular terminal aperture. Length of holotype, 1.6 mm.; greatest breadth, 0.17 mm.; diameter of megalosphere, 0.05 mm. The diameter of the tubular chambers expands from the proloculum to a breadth of about 0.2 mm. or less at a length of about 0.6 mm., from which point expansion is generally almost negligible."

Dimensions.—Text-figure 3—14: length, 0.40 mm.; diameter of tube, 0.04 mm.: Text-figure 3—16: length, 0.90 mm.; diameter of tube, 0.09 mm.

Occurrence.—Found in Toronto member of Oread limestone, Ervine Creek member of Deer Creek formation, Curzon member of Topeka limestone, Burlingame and Reading limestones. It is the most common in the Curzon. Plummer found this species in the Upper Strawn shales of central Texas.

Remarks.—Text-figure 3—14 is a very small specimen and appears to be the microspheric form.

HYPERAMMINA GLABRA
Cushman & Waters, 1927
Text-fig. 3—17–19

Hyperammina glabra CUSHMAN & WATERS, 1927, Contr. Cushman Lab. Foram. Res., vol. 3, p. 146, pl. 26, fig. 1.

"Test elongate, consisting of an oval proloculum and an elongate tubular second chamber, tapering from the narrowest diameter near the proloculum to the greatest width near the aperture end; wall of fine arenaceous material with much cement; aperture formed by the open end of the tube. Length of holotype 1.35 mm.; greatest diameter 0.20 mm.; diameter of proloculum 0.15 mm."

Dimensions.—Text-fig. 3—18: length, 1.27 mm.; greatest diameter of tube, 0.18 mm.; diameter of proloculus, 0.09 mm.

Occurrence.—Found in many beds throughout the Virgilian series. The best and most common specimens were in the lower 2 feet of the Kereford member of the Oread limestone (Coll. A3). Cushman & Waters found this species near the top of the Strawn (1927b) and in the South Bend shale of the Cisco (1930).

Family REOPHACIDAE Cushman, 1927
Subfamily REOPHACINAE Cushman, 1927
Genus NODOSINELLA H. B. Brady, 1876
NODOSINELLA PERELEGANS
Plummer, 1930
Text-fig. 3—21

Nodosinella perelegans PLUMMER, 1930, Univ Texas Pub. 3019, p. 14, pl. 1, fig. 5a,b.

Test free, elongate, slightly curved; globular proloculum followed by a linear series of 8 or more segments each larger than the one preceding and separated by poorly defined constrictions showing little depression; wall thick composed of uniform size quartz grains well cemented; surface smooth; aperture at end of last segment.

Dimensions.—Length, 0.63 mm.; diameter of last chamber, 0.08 mm.; diameter of proloculum, 0.02 mm.

Occurrence.—Ervine Creek member of Deer Creek limestone (Coll. A11).

Remarks.—Only one specimen was found and I did not wish to destroy it by sectioning; the segments appear to be chambers and it is classified as *Nodosinella*. Plummer describes the species from the Brownwood shale in central Texas where it is calcareous. I hesitate to describe a new species on the basis of one specimen and because the only difference is in the material composing the test. However, Plummer's statement (1930, p. 70) and Brady's (1876, p. 102) would indicate that the quartzose arenaceous form should be described as different from the calcareous.

Family AMMODISCIDAE Rhumbler, 1895
Subfamily AMMODISCINAE
Rhumbler, 1895
Genus AMMODISCELLA
Ireland, n. gen.
Type species: *Ammodiscella virgilensis*, n. sp.

Test attached, composed of proloculum and tubular second chamber coiled planispirally or with the last one or two coils curving up over the top of the test and overlapping the earlier coils; whorls range from four to six in number; wall composed of fine uniform quartz of silt size; surface smooth; aperture at the end of the last whorl.

AMMODISCELLA VIRGILENSIS
Ireland, n. sp.
Text-fig. 3—22–28

Test attached composed of proloculum and tubular second chamber coiled planispirally or with last one or two coils curving upward over the top of the test and overlapping the earlier coils; whorls range from four to six in number; wall composed of fine uniform quartz sand; surface smooth; aperture at the end of the last whorl.

Dimensions.—Holotype, Text-fig. 3–26a, b; length, 0.35 mm.; width, 0.30 mm.; thickness, 0.02 to 0.08 mm.; text-fig. 3–22a, b: diameter, 0.20 mm.; thickness, 0.02 mm.

Occurrence.—Found in nearly all limestone members of the Shawnee and Wabaunsee groups above the top of the Lecompton

limestone, and at most localities. Holotype from Coll. A17, Utopia limestone.

Remarks.—This species is clearly an Ammodiscinae attached to some surface. Viewed from the top it looks like the typical coiled form, but from the bottom the interior of the coils are visible when the object of attachment is removed. The exposure is not a result of breaking one side of the delicate test because there are many of such for comparison and the flat surface of attachment is quite distinct. The side view also shows the angular contact with the surface of attachment. Some forms when attached to an object smaller than the full grown test may have the last coil overlapping the edge of the object. When the object is dissolved a coil with a rolled-over edge may be seen (Text-fig. 3—28), which might give the impression that the side of the form had been broken revealing the interior. Text-figures 3—22 and 3—23 are believed to be immature forms wholly confined to the surface of the object of attachment and have not overlapped the edge.

This species appears to be an evolutionary transition from *Ammodiscus* with a free test to an attached test and then into *Ammovertella*, for there are attached forms of *Ammovertella* which resemble it. However, the tube of *Ammovertella* shows a reversal of direction as it enlarges from the proloculus while *Ammodiscus* is coiled. Both *Ammovertella* and *Ammodiscus* show overlapping of the final one or two coils.

Ammodiscella resembles *Calcitornella heathi* Cushman & Waters (1930). However, that form is calcareous and the Kansas form is composed of quartz silt.

Holotype.—U.S.N.M., P2035.

Genus Ammodiscus Reuss, 1861

Ammodiscus annularis (H. B. Brady), 1876

Text-fig. 4—4–6

Trochammina annularis H. B. Brady, 1876, Pal. Soc., vol. 30, p. 76, pl. 3, fig. 9, 10.

Ammodiscus annularis Cushman & Waters, 1927, Contr. Cushman Lab. Foram. Res., vol. 3, p. 108, pl. 22, fig. 3a,b.

Description of Cushman & Waters: Test minute, planispiral or somewhat irregular, consisting of a proloculum and elongate tubular second chamber of even diameter, nearly circular in section; wall coarsely arenaceous for the size of the test; aperture formed by the open end of the tube, nearly circular. Maximum diameter, 0.17 mm.

Dimensions.—Diameter, 0.15 to 0.20 mm.

Occurrence.—Common in nearly all Virgilian limestones at most localities.

Remarks.—The original description by Brady was of specimens having only the outer coils preserved. The centers are very thin and fragile and easily lost and many of the Virgilian specimens lack centers. Most forms have a planispiral coil but many have slight irregularities out of the plane of coiling. All forms are very small. Cushman & Waters (1927a) found this species in Michigan. The specific differences in small *Ammodiscus* are difficult to determine; this form could be identified as *A. incertus* d'Orbigny which has been recognized in the Silurian (Ireland, 1939) but was originally described from the Recent. The specimens are much too small to be *A. semiconstrictus* var. *regularis* Waters.

Ammodiscus semiconstrictus Waters, 1927

Text-fig. 4—1–3

Ammodiscus semiconstrictus Waters, 1927, Jour. Paleont., vol. 1, p. 132, pl. 22, fig. 1.

Test nearly circular, planispiral biconcave; proloculum small, ovoid; tubular second chamber oval in transverse section, irregularly constricted, open at the terminal end, about nine coils in the adult test; wall coarsely arenaceous, the sand grains cemented with a small proportion of cement; aperture a circular opening at the end of the tubular chamber; color, white. Diameter of test, 1.0 mm.; diameter of tube at aperture, 0.1 mm.; thickness of wall at aperture, 0.03 mm.

Dimensions.—Diameter, 0.25 to 0.40 mm.

Occurrence.—Abundant in Kereford member of Oread limestone, in Big Springs member of Lecomptom limestone, in all beds of the Deer Creek and Topeka limestones, abundant in the Church and Utopia members of Harvard limestone. It has not been found above the Howard limestone in the Wabaunsee group. Waters (1927) described the species from the Dornick Hills formation in the Ardmore Basin, and Plummer (1945) found the species in the Smithwick and lower Strawn formations in central Texas.

Remarks.—Some samples, particularly those of the upper Deer Creek and the

Topeka and Howard limestones were composed of 50 percent, or more, of *Ammodiscus*.

Genus GLOMOSPIRA Rzehak, 1888

GLOMOSPIRA ARTICULOSA Plummer, 1945

Text-fig. 4—7–10

Glomospira articulosa PLUMMER, 1945, Univ. Texas Pub. 4401, p. 233, pl. 16, fig. 21–25.

"This tight tangle of disorderly convolutions of a very slowly enlarging tubular chamber is the Gordian Knot of the foraminiferal structures in Pennsylvanian faunas in this area. It apparently follows no formal plan of coiling, but twists and turns about itself haphazardly, winding itself into a compact body of no definite shape. The shell wall is composed of very minute quartz particles bound by considerable clear and insoluble cement. Transverse constrictions are frequent but not consistently present. The whorl suture is not sharply depressed. The aperture is the open end of the tube but can rarely be found. The diameter of the holotype, which happens to be one of the more nearly globular tests, is about 0.5 mm. Transverse measurements of these irregular tests can reach 0.7 mm., and they average about 0.5 mm. The diameter of the mature tube averages about 0.1 mm."

Dimensions.—Diameter, 0.18 to 0.30 mm.

Occurrence.—Found in Kereford member of Oread limestone, Spring Branch (Coll. B5), and Avoca member of Lecompton limestone. It is found in nearly all of the lower Wabaunsee beds, but is most common in Church, Utopia, Rulo, Wakarusa, and Reading limestones. Plummer found it in the Strawn of central Texas.

Remarks.—Form in Text-fig. 4—7 is coiled about another form of *Ammodiscus*.

GLOMOSPIRA MONOGRANULA Ireland, n. sp.

Text-fig. 4—11–14

Test composed of proloculum and long winding tube, proloculum attached to a single large quartz grain and the tube winds about it planispirally or randomly; walls composed of very fine quartz particles well cemented; surface smooth; aperture at the open end of the tube.

Dimensions.—Holotype; Text-fig. 4—14, diameter, 0.18 mm., average size. Diameter of quartz grain, 0.06 mm.

Occurrence.—Common in the Ervine Creek member of the Deer Creek limestone (Coll. A11), also in the Curzon member of the Topeka limestone (Coll. A13). Abundant in the upper Wabaunsee in the Maple Hill limestone, where holotype was selected (Coll. A24).

Remarks.—Some specimens look like a typical coiled *Ammodiscus* (Text-fig. 4—13a), others like *Glomospira* (Text-fig. 4–12), and there are gradations between them. The unique and consistent attachment around a quartz grain differentiates the species. The specimen illustrated showing advanced *Glomospira* affinities has the tube projecting free of the main test.

Holotype.—U.S.N.M., P2036.

GLOMOSPIRA PUSILLA (Geinitz), 1848

Text-fig. 4—15–17

Serpula pusilla GEINITZ, 1848, Verstein. deutsch, Zechstein., pt. 1, p. 6, pl. 3, fig. 46.

Trochammina pusilla JONES, PARKER & KIRKBY, 1869, Ann. Mag. Nat. Hist., ser. 4, vol. 4, p. 39, pl. 13, fig. 4–6, 15. H. B. BRADY, 1876, Pal. Soc. Mono. 30, p. 78, pl. 3, fig. 4,5.

Glomospira pusilla CUSHMAN & WATERS, 1927, Contr. Cushman Lab. Foram. Res., vol. 3, p. 108, pl. 22, fig. 1a,b.

There are abundant specimens representing this species. Irregularity of form in the earlier figures of the synonymy show more plainly than in those of Brady. The one figured here is one of the more regular ones. The test is arenaceous irregularly winding, usually broader than thick.

Dimensions.—Average diameter, 0.28 mm.

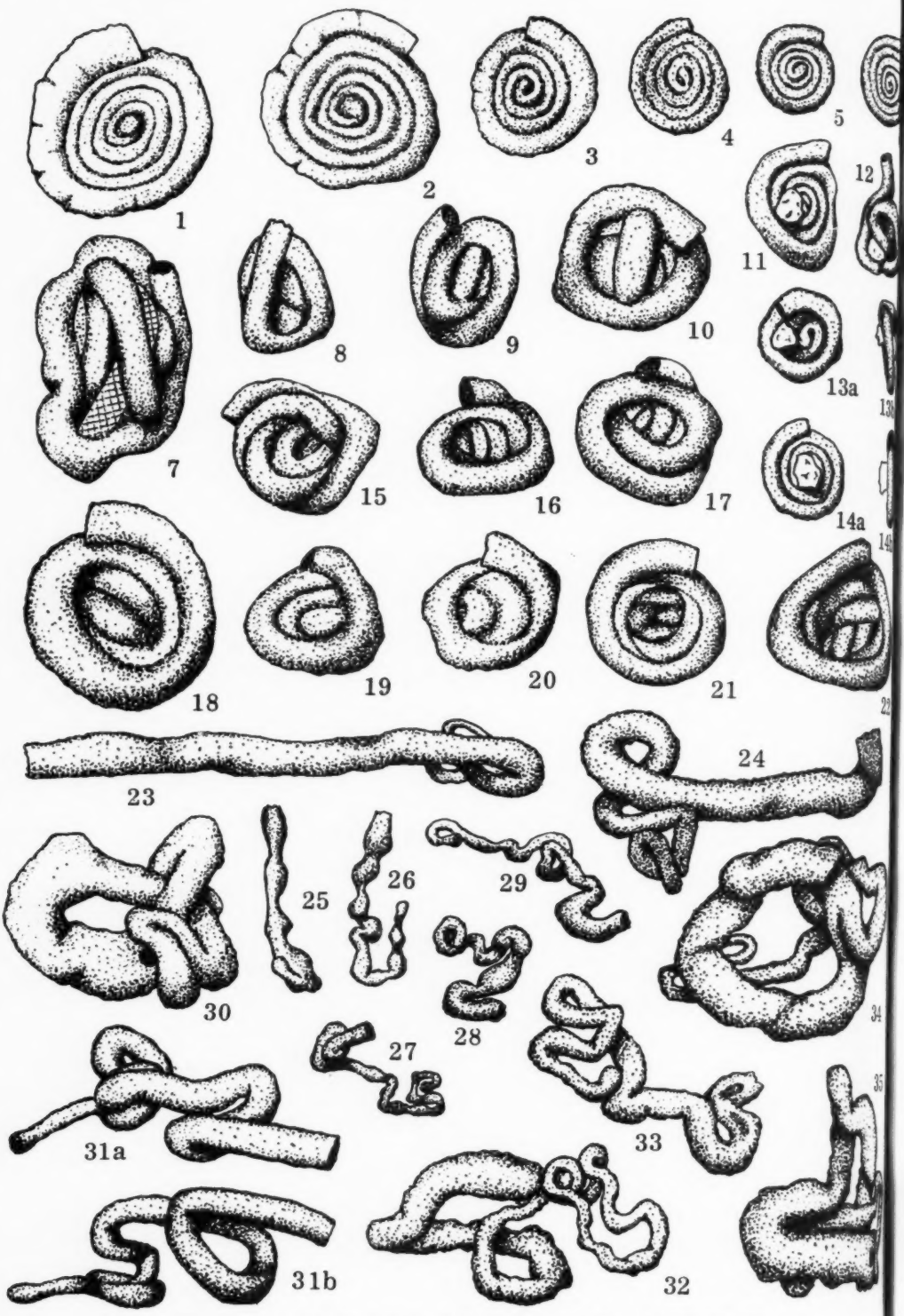
Occurrence.—Abundant in all beds where found: Kereford member of Oread limestone, all members of Deer Creek limestone, Curzon, Sheldon (Coll. B14), and Coal Creek (Coll. B16) members of Topeka limestone, Church, Utopia, and Maple Hill limestones. The Kansas specimens are somewhat smaller than the forms described from Michigan by Cushman & Waters (1927a).

GLOMOSPIRA SIMPLEX Harlton, 1928

Text-fig. 4—18–20

Glomospira simplex HARLTON, 1928, Jour. Paleont., vol. 1, p. 305, pl. 52, fig. 2a–c.

"Test free, trochoid, nearly round, peripheral margin rounded, with subcircular or ovoid proloculum and a long undivided second chamber,



TEXT-FIG. 4—Virgilian Foraminifera, ×80 (*1–22*) and ×60 (*23–35*).

at first planispiral but soon becoming irregular; wall finely arenaceous with a large proportion of cement; aperture round, simple, terminal. Diameter of holotype, 0.33 mm."

Dimensions.—Diameter, 0.18 to 0.36 mm.

Occurrence.—Found in Ozawkie and Ervine Creek members of Deer Creek limestone, and in the Coal Creek member (Coll. B16) at the top of the Topeka limestone. In the Wabaunsee it occurs in the Church, Utopia and Reading limestones. Harlton found it in beds in West Texas called Gaptank or possible Dimple. Cushman & Waters (1930) found it in central Texas below the Bunger limestone and above the Gunsight limestone of the Cisco.

Genus GLOMOSPIRELLA Plummer, 1945

GLOMOSPIRELLA UMBILICATA
(Cushman & Waters), 1927
Text-fig. 4—21,22

Glomospira umbilicata CUSHMAN & WATERS, 1927, Contr. Cushman Lab. Foram. Res., vol. 3, p. 148, pl. 26, fig. 7,8.
Glomospirella umbilicata PLUMMER, 1945, Univ. Texas Pub. 4401, p. 233, pl. 16, fig. 26–31.

Test large, discoidal, broadly umbilicate, uniform texture with fine quartz sand grains and considerable insoluble cement. In initial stage, tube winds compactly but irregularly with two to five convolutions; later at different planes at low angle to the general plane and bending in later stages toward a planispiral character. Sutures distinct and compressed; aperture at open end of tube.

Dimensions.—Diameter, 0.28 to 0.35 mm.

Occurrence.—Found in Coal Creek member (Coll. B16) of Topeka limestone, abundant in Utopia limestone, also found in Reading limestone. Plummer (1945) found the species in the Smithwick, Marble Falls, and lower Strawn beds of central Texas.

TOLYPAMMINA EXTENDA
Ireland, n. sp.
Text-fig. 4—23,24

Test attached, consisting of proloculum with tubular second chamber coiled in the initial stage. A loosely winding early stage which extends in one direction; the extended portion may have a few twists or minor bends which do not deviate significantly from the general direction of growth. The tube enlarges very rapidly as the extended portion begins and then does not further enlarge. Walls of medium to fine quartz silt, well cemented; surface smooth to slightly rough; aperture at open end of tube.

Dimensions.—Holotype, Text-figure 4–23: early winding portion, 0.15 to 0.45 mm. across; diameter of extended tube, 0.10 mm.; length of extended tube, up to 1.25 mm. or more.

Occurrence.—Found in Toronto and Plattsmouth members of Oread limestone, Spring Branch and Avoca (holotype) members of Lecomptom limestone (Colls. B5 and B8), and in Du Bois limestone.

Remarks. Excellent specimens were found

EXPLANATION OF TEXT-FIG. 4

1-3—Ammodiscus semiconstrictus Waters.
4-6—Ammodiscus annularis (H. B. Brady).
7-10—Glomospira articulosa Plummer. Form in *7* is coiled about another form of *Ammodiscus*.
11-14—Glomospira monogranula Ireland, n. sp.
11, proloculum attached to large sand grain.
12, irregularly coiled form around a single sand grain.
13a, top view of holotype, proloculum attached to single sand grain; *13b*, side view.
14a, planispirally coiled form, proloculum attached to large sand grain; *14b*, side view.
15-17—Glomospira pusilla (Geinitz).
18-20—Glomospira simplex Harlton.
21, 22—Glomospirella umbilicata (Cushman & Waters).
23, 24—Tolypammina extenda Ireland, n. sp. *23*, holotype, top view; *24*, bottom view, attached only on flattened areas at small and large ends.
25-29—Tolypammina nodosa Ireland, n. sp. Top view of all specimens, attached only at proloculum area and a few other spots where tube bends downward. Holotype, *26*.
30-35—Tolypammina polyverta Ireland, n. sp.
30, top view.
31a, top view; *31b*, side view, attached only at two points.
32, bottom view.
33, holotype, bottom view.
34, 35, typical forms, top view.

of this species. It is something like *T. delicatula* Cushman & Waters but generally has less than one coil and enlarges more quickly after the early stage.

Cushman & Waters (1928c, p. 47) describe a *Calcitornella elongata* from Cisco beds in Texas which resembles this species; it has calcareous walls. Galloway & Ryniker (1930, p. 10) change Cushman & Waters' generic reference from *Calcitornella* to *Ammovertella* and describe it as calcareous, but their figures and description show it to be a *Tolypammina*-like form. The original name, *Calcitornella*, should stand because *Ammovertella* is an arenaceous form. The question as to whether a genus may have both calcareous and arenaceous species, especially in the same bed, is not settled. The specimens used for the original descriptions of *C. elongata* should be rexamined.

Ammovertella elongata (Cushman & Waters), as figured by Galloway & Ryniker, is probably synonymous with *Tolypammina grahamensis* Harlton, which is referred to the Ophthalmidiidae and called *Apterrinella grahamensis* (Harlton) by Cushman (1928). *Tolypammina* is consistently called *Ammovertella*, and vice versa, by Galloway & Harlton (1928) and Galloway & Ryniker (1930).

Holotype.—U.S.N.M., P2037.

TOLYPAMMINA NODOSA
Ireland, n. sp.
Text-fig. 4—25–29

Early part of test attached, most of the later portion free with occasional contact with the object of attachment for support of the long tubular test. Test consists of proloculum and long tube not much larger in diameter than the proloculum; tube with less than one coil or not coiled, inflated at irregular intervals with constrictions between giving the nodal appearance; wall of fine quartz particles well cemented; surface smooth; aperture at end of open tube, in some cases with a slight constriction.

Dimensions.—Length up to 0.40 or 0.50 mm.; maximum diameter of tube, 0.08 mm.; diameter of coil, 0.10 mm.

Occurrence.—Found in Toronto (Colls. A1 and B1), Plattsmouth and Kereford members of Oread formation; in Avoca member of Lecompton; in Ervine Creek member of Deer Creek limestone; in Curzon member of Topeka limestone; and the Wakarusa and Dover limestone of the Wabaunsee group.

Remarks.—This species differs from all others by having a series of constricted and inflated portions of the tube. Other *Tolypammina* enlarge gradually and have only occasional slight constrictions where bent, and do not have a series of highly inflated portions as does this new species. This is the smallest of all *Tolypammina* seen. Holotype, Text-figure 4—26, from Toronto limestone (Coll. B1).

Holotype.—U.S.N.M., P2038.

TOLYPAMMINA POLYVERTA
Ireland, n. sp.
Text-fig. 4—30–35

Test attached and composed of proloculum and tubular second chamber, attached at proloculum and along portion of initial tube, most of the tube free but attached at various points to add support to the test. Generally less than one whorl or no whorl developed around the proloculum, tube enlarged gradually, twisted randomly in many directions but generally back to the vicinity of the proloculum. Walls are of medium to fine quartz silt with abundant cement; surface smooth to slightly rough; aperture at the end of tube, sometimes with a definite constriction.

Dimensions.—Average distance across intertwined tubes, 0.75 mm.; average diameter of tube at proloculum, 0.02 mm.; diameter of tube at end 0.12 to 0.20 mm.

Occurrence.—This species is the most common *Tolypammina* found in the Virgilian and nearly every collection contained specimens.

Remarks.—This species is very common and in some samples comprises 25 to 50 percent of the Foraminifera present. It is commonly associated with *Ammovertella* but differs from them by having a circular whole tube and not the object of attachment as part of the tube. Due to the fragile tubes which extend unsupported, whole specimens are not common and dozens or hundreds of segments of various diameters may be found in a sample. All forms of this species are intermediate between the very small *Tolypammina* such as *T. serpens* and *T. nodosa* and the large forms such as *T. rugosa*. This

species is much more sinuous than *T. delicatula* Cushman & Waters, and is much larger than the Recent species *T. vagans* (H. B. Brady).

It is difficult to select a typical example but the specimen in Text-figure 4—33 has been selected as holotype of *T. polyverta*. It is from the basal part of the Kereford (Coll. B4).

Holotype.—U.S.N.M., P2039.

TOLYPAMMINA RUGOSA Ireland, n. sp.
Text-fig. 5—1,2

Test attached in initial stage, large, consists of proloculum and tubular second chamber which randomly bends back and forth over initial area during most of the development but may become extended. Tube enlarges slowly in earlier portion, but more gradually and to a large diameter in later stage. At points of attachment the bottom of the test generally has agglutinated material and object of attachment does not serve as part of the wall; where attached to any part of earlier tube, new material is added to form the new tube. Attachment is restricted to proloculum and initial part of tube, later parts may be attached for a short length to support the test. Objects of attachment may be very small and tube may bend around on all sides and even obscure the original object of attachment. Walls composed of medium to coarse quartz silt well cemented, surface rough; aperture at end of tube.

Dimensions.—Length of tube up to 3.00 mm.; diameter of end of tube, 0.32 mm.; diameter of tube near proloculum, 0.04 mm.

Occurrence.—Found in most of the beds of the Virgilian series (Table 1).

Remarks.—This is the largest of the *Tolypammina* seen. Its distinguishing characteristics are the large size, coarseness of grains. Broken portions are very common. Most of the test is unattached. Masses of intertwined tubes may be seen in some samples.

Holotype.—U.S.N.M., P2040

TOLYPAMMINA SERPENS Ireland, n. sp.
Text-fig. 5—3–5

Test attached throughout most of its length, consists of proloculum with one or two whorls and a tubular second chamber which bends back and forth in a more or less regular manner, tube gradually enlarging; walls thin composed of fine quartz silt well cemented, walls complete and object of attachment rarely serves as part of the wall, only as a surface to which the outside of the test is cemented; surface smooth; aperture at the open end of tube.

Dimensions.—Diameter of the tube at end, 0.08 mm.; diameter of coil, 0.10 to 0.17 mm.; length, generally less than 0.50 mm.

Occurrence.—Found abundantly in the Hartford member of Topeka limestone, and many other good specimens are in the Burlingame, Wakarusa, Reading and Dover limestones. Holotype (Text-fig. 5—3) from the Wakarusa limestone.

Remarks.—This species is very small and bends in a more or less uniform sinuous manner. It resembles the figures and description of *Ammovertella undulata* Galloway & Harlton; that species is calcareous and the Kansas form is definitely composed of quartz silt grains and is a true *Ammovertella*. *A. undulata* should be referred to *Calcitornella*.

Holotype.—U.S.N.M., P2041

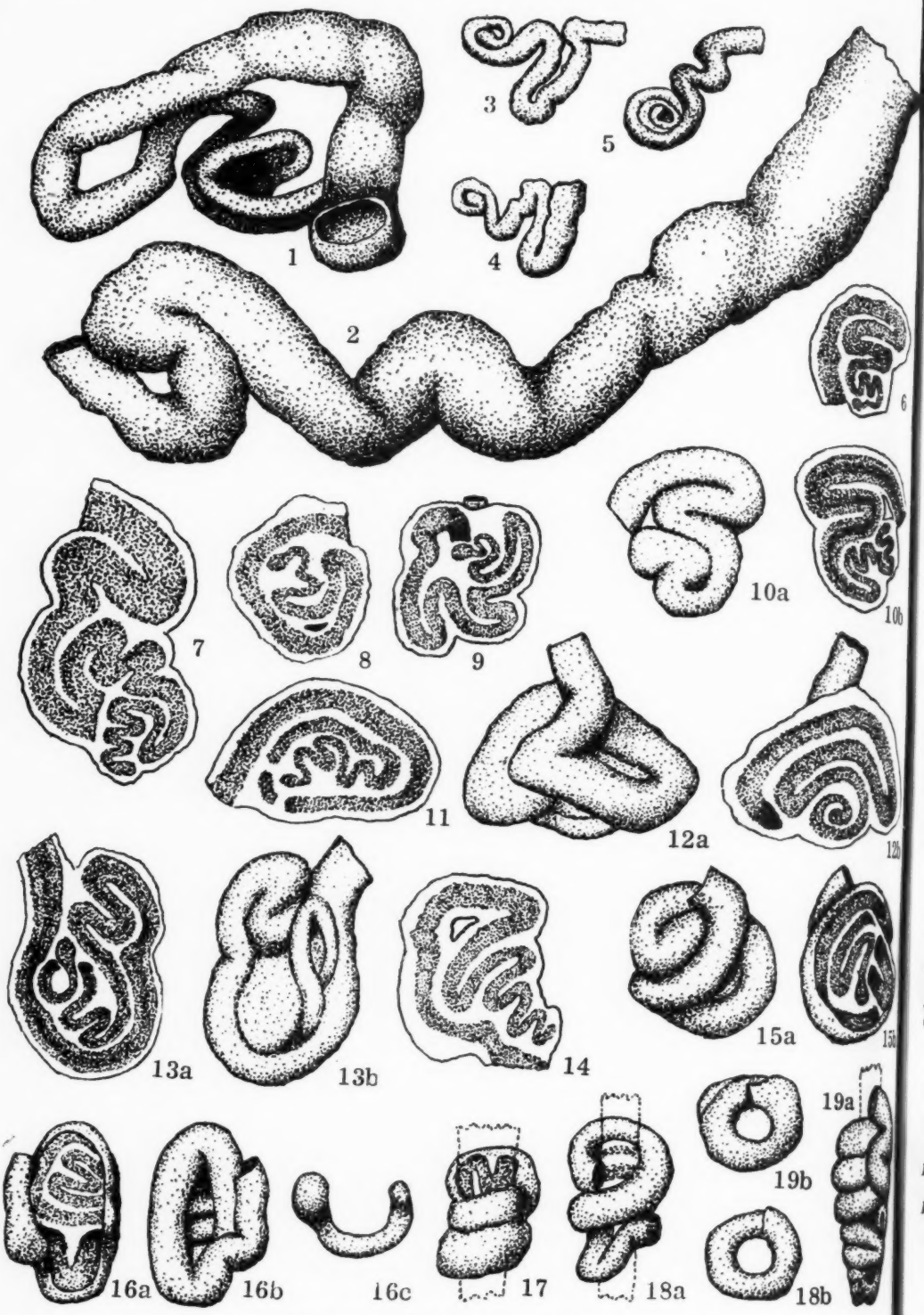
Genus AMMOVERTELLA Cushman, 1928
AMMOVERTELLA ELEVATA Ireland, n. sp.
Text-fig. 5—15

Test roughly equidimensional or slightly elongate, attached to a flat or curved surface, consists of a proloculum and sinuous tubular second chamber, the surface of the object of attachment serves as a floor. Tube enlarges gradually, flexed back and forth in a plane in early stages with a common wall between adjacent portions of the tube; in later stage extended over the earlier tube and randomly over the top of the test, elevating it. Walls of fine silt grains well cemented; surface smooth; aperture at end of open tube.

Dimensions.—Diameter, 0.30 mm.; height, 0.10 to 0.20 mm.; diameter of tube at end, 0.09 mm.

Occurrence.—Found in Toronto and Plattsmouth members of Oread limestone, Ozawkie member of Deer Creek formation, Sheldon member of Topeka limestone, and in Reading limestone. Holotype from Sheldon limestone.

Remarks.—This species is similar and



TEXT-FIG. 5—Virgilian Foraminifera, ×60.

undoubtedly related to representatives of *Ammodiscella*, but in the early stage the tube bends back and forth in a plane instead of a coil. The tube of *Ammodiscella* may wind over the top of the test in a late stage, but *Ammovertella elevata* has a much higher and thicker build-up of the test and the tube is much larger in diameter. Other *Ammovertella* are rarely equidimensional, have many more bends in the same plane, and many of them do not have the tube curving back over the test.

Holotype.—U.S.N.M., P2042

AMMOVERTELLA INCLUSA (Cushman & Waters)

Text-fig. 5—6–14

Psammophis inclusus, CUSHMAN & WATERS, 1927, Contr. Cushman Lab. Foram. Res., vol. 3, p. 148, pl. 26, fig. 12.

Tolypammina inclusa GALLOWAY & RYNIKER, 1930, Okla. Geol. Survey, Circ. 21, p. 11, pl. 1, fig. 12,13.

Ammovertella inclusa CUSHMAN & WATERS, 1930, Univ. Texas Pub. 3019, p. 44, pl. 7, fig. 13.

Description of Cushman & Waters: Test attached, basal side flattened, dorsal side convex, consisting of a proloculum and elongate tubular chamber, the latter in its early stages close-coiled planispirally, later the tube swinging back and forth about the early portion and partially embracing it; wall finely arenaceous with much cement and the dorsal surface somewhat roughened; aperture formed by the open end of the tubular chamber. Maximum diameter of the holotype 0.85 mm.

Dimensions.—Specimens range from 0.25 to 0.75 mm. in width or length, but generally are about 0.50 mm. wide with the tube at the end 0.10 mm. in diameter. Text-figure 5—12 is 0.60 mm. wide with a tube diameter of 0.10 mm. at the end.

Occurrence.—Found in all limestone beds of the Virgilian and is very abundant in most of them. Cushman & Waters found the species in the South Bend shale of the Graham formation of the Cisco beds in central Texas.

Remarks.—The Virgilian beds of Kansas contain large numbers of this species which are distinctly arenaceous. In some samples 80 to 90 percent of the Foraminifera are *Ammovertella*. The Sheldon member of the Topeka limestone (Coll. A14) contains hundreds of perfectly preserved whole specimens.

Previously, a single illustration of *A. inclusa* has been used. It is a dorsal view which gives no clue to the form of the underside.

All specimens fit the original description closely. Though there is variation in the shape of the test a consistent pattern prevails. With the large number of specimens available, little question arises about all of them being the same species. Individually, the various types might suggest several different species. A significant observation is that all show a lack of the lower wall for most of the tubular chamber, though many become round and unattached for a very short distance near the aperture. Many have the final portion of the tube bent back over the test and attached to it. Some specimens have a slight roll of the edge of the tube

EXPLANATION OF TEXT-FIG. 5

1,2—Tolypammina rugosa Ireland, n. sp. *2* is an example of the large size attained in the late stage of growth.

3-5—Tolypammina serpens Ireland, n. sp. Holotype, *3*.

6-14—Ammovertella inclusa (Cushman & Waters).

6-9, typical shapes of test showing bottom sides of attachment, all showing the bending in a plane during the early stage.

10a, top view; *10b*, bottom view.

11, bottom view.

12a, top view showing termination as unattached tube; *12b*, bottom view.

13a, bottom view; *13b*, top view.

14, bottom view showing typical bending of early and late stages.

15—Ammovertella elevata Ireland, n. sp. *15a*, top view showing sinuous winding over the top elevating it and increasing the thickness; *15b*, bottom view.

16-19—Ammovertella tornella Ireland, n. sp.

16a, bottom view showing partial coil around brachiopod spine; *16b*, top view; *16c*, end view showing partial coil around spine.

17, side view showing attachment along and around spine.

18a, side view similar to *17*; *18b*, apertural view.

19a, side view showing complex coiling around end of spine; *19b*, apertural view, holotype.

around the perimeter of the test, apparently an extension over the edge of the object of attachment. If good forms could be secured from shale without solution of the object of attachment, more could be learned.

Galloway & Ryniker (1930, p. 11, pl. 1, fig. 12) illustrate and describe *Tolypammina inclusa* (Cushman & Waters) changing the generic reference from *Ammovertella*. The form is a *Tolypammina* but it is not the same as *A. inclusa*. *A. latimerensis* of Galloway & Ryniker (Pl. 1, fig. 8,9) has all the appearances of *Ammovertella inclusa* but the forms are described as calcareous, and, therefore, should be classed with *Calcitornella*. In the same publication, *A. adherens* (Cushman & Waters) should also be referred to *Calcivertella* as was done originally by Cushman & Waters (1928c).

A sample of Grenola limestone of Permian age has been found to contain abundant well-developed *A. inclusa*, an indication of long vertical range for the species.

AMMOVERTELLA LABYRINTHA Ireland, n. sp.
Text-fig. 6—1,2

This species is composed of multiple forms with tubes which are aggregated and built one on top of the other into an indeterminate mass, hundreds of tubes intertwined and overlaid. It is difficult to cite a specific characteristic except the gregarious habit. Rare specimens of what appears to be *A. inclusa* may be seen on the bottom of some masses, probably not an initial part of the mass. Individual *Ammovertella* tests found in the same sample show no gradation toward the composite accumulation. The masses are generally incrusted on shell fragments and conform to the surface irregularities.

Dimensions.—The masses range from 0.50 to over 4.00 mm. across, and up to 1 or 2 mm. thick. Tube channels range from 0.005 to 0.03 mm. wide.

Occurrence.—Abundant in the Kereford member of the Oread limestone (Coll. B4), and in the Du Bois and Coal Creek members of the Topeka limestone (Colls. B15, B16). It is also very abundant in the Church and Utopia limestones of the Wabaunsee group and scattered through several other beds of the Virgilian series. It has no particular stratigraphic value for it also occurs in Permian beds.

Holotype.—U.S.N.M., P2043

AMMOVERTELLA PRIMAPARVA Ireland, n. sp.
Text-fig. 6—8–12

Test attached, very small, composed of proloculum and narrow tubular second chamber which in early stage bends back and forth in the same plane. Initial stage generally lacks a coil, but a single whorl may be developed; tube gradually enlarges but after four to six traverses across the test the tube becomes extended, bends less, and develops in more random directions. The test is generally wedge-shaped with a constriction at the point where the tube begins to extend. Walls of quartz silt poorly cemented, fragile; surface smooth to slightly rough, aperture at end of open tube.

Dimensions.—Holotype, Text-figure 6–10: lower portion, 0.25 mm. wide, length of whole test 0.60 mm.; diameter of tube channel near proloculum 0.02 mm.; diameter of channel near end, 0.07 mm.

Occurrence.—Found in Kereford member of Oread limestone, Ozawkie and Ervine Creek members of Deer Creek limestone, Coal Creek member of Topeka limestone (Coll. B16), and in Utopia limestone. Holotype is from Coal Creek limestone, where specimens are abundant.

Remarks.—This species is very small and because of the constriction many specimens break and only the early portion is found. The tube bends back and forth but rarely turns back over the initial part as does *A. inclusa*, *A. elevata*, and others. For this reason *A. primaparva* is not considered to be the microspherical form of some of the other species.

Holotype.—U.S.N.M., P2044

AMMOVERTELLA PRODIGALIS Ireland, n.sp.
Text-fig. 6—3–7

Test attached, consisting of proloculum and sinuous second chamber which gradually enlarges, surface of object of attachment serves as a bottom wall. In some cases, a portion of the tube may be unattached, generally the terminal portion. In the early stage the tube bends back and forth several

times in a plane with common walls between bends and then extends away from the main body and continues more or less linearly to the end, or it may loop back over the initial area to terminate. Walls well-cemented, composed of medium silt grains; surface smooth to slightly rough, sutures on top not well defined; aperture at open end of tube.

Dimensions.—Length, 0.40 to 0.75 mm. or more; diameter of tube at end 0.06 to 0.10 mm. Holotype, Text-figure 6—6: from Utopia limestone.

Occurrence.—Not abundant but found in several beds; Ozawkie member of Deer Creek formation, Du Bois and Coal Creek members of Topeka formation, Church, Utopia and Grandhaven limestones.

Remarks.—The name was selected because the tube extends out and then back again to point of origin. This species has some resemblance to representatives of *Tolypammina* in that some of the tube in the late stage may be round and it may bend back over the test. Part of the loop may be controlled by the shape of the object of attachment, but the habit of extension is different from other *Ammovertella*. The *Ammovertella* habit of sinuous bending in a plane is distinct from the coiling habit of *Ammodiscus* and *Ammodiscella*.

Holotype.—U.S.N.M., P2045

AMMOVERTELLA TORNELLA Ireland n. sp.
Text-fig. 5—16–19

Test attached, generally coiled about a brachiopod spine, test consists of proloculum and tubular second chamber which in the initial stage winds back and forth along the spine; in a later stage the tube coils about the spine, overlapping the initial stage. Coils may be spiral and enclose spine or only cover part of it and the last part of the tube may bend back over the earlier coils. Walls thin, composed of medium to fine quartz silt well cemented; surface smooth; aperture at the open end of the tube.

Dimensions.—Holotype, Text-figure 5—19: length, 0.53 mm.; maximum diameter, 0.27 mm.; diameter of center, 0.08 mm.

Occurrence.—Abundant in Sheldon member of Topeka limestone, also in Coal Creek member.

Remarks.—The holotype encased the point of the spine, in other specimens the spine extended through the whole test. Text-figure 5—16 illustrates a form which did not completely encircle the spine.

Holotype.—U.S.N.M., P2046

Family LITUOLIDAE Reuss, 1861
Subfamily HAPLOPHRAGMIINAE
Cushman, 1927
Genus AMMOBACULITES Cushman, 1910
AMMOBACULITES GRACILIS Waters, 1928
Text-fig. 6—13–16

Ammobaculites gracilis WATERS, 1928, Jour. Paleont., vol. 1, p. 274, pl. 42, fig. 4a,b.

"Test minute, slender, slighlty rough, tapering from final to initial chamber, planispiral in early portion, five chambers in number; later portion numbering six chambers, uncoiled in linear arrangement; wall arenaceous, fine sand with siliceous cement; sutures well depressed; aperture circular, central and terminal; color, white. Length, 0.90 mm.; diameter of final chamber, 0.21 mm.; diameter of coil, 0.26 mm."

Dimensions.—Length in Text-figure 6—14, 0.32 mm.; diameter of coil, 0.10 mm.; diameter of last chamber, 0.09 mm. Text-figure 6—13, microspheric form: length, 0.48 mm.; width, 0.11 mm.; coil, 0.08 mm.

Occurrence.—Abundant in the Kereford member of the Topeka limestone, also present in Avoca member of Lecompton limestone. Waters found it in the Canyon group below the Ranger limestone in central Texas.

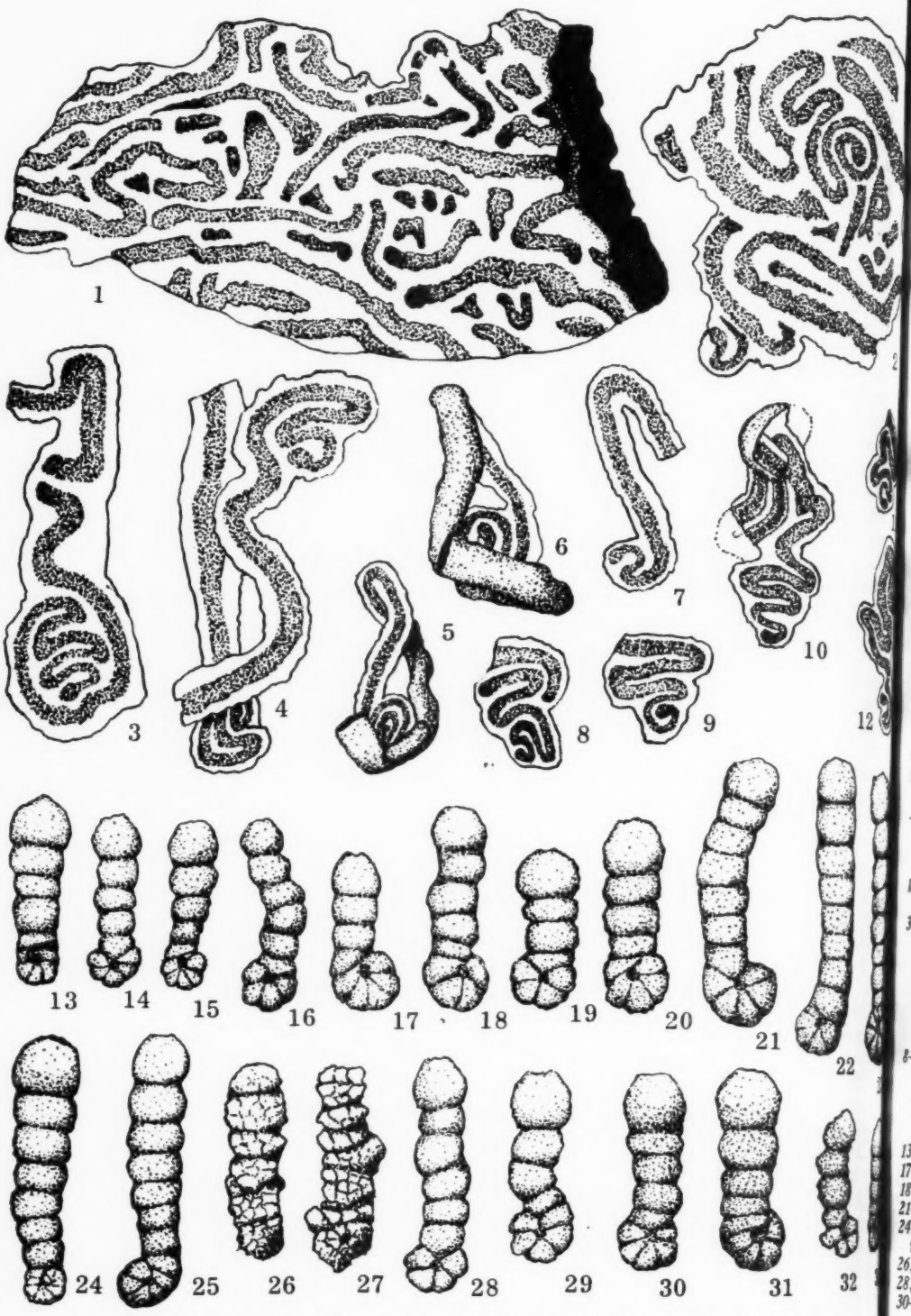
Remarks.—This Kansas form is less than half the size of the Texas form, but the ratios are about the same. The smooth test with well-cemented walls of quartz silt is typical.

AMMOBACULITES INCONSPICUUS Cushman & Waters, 1928
Text-fig. 6—24,25

Ammobaculites inconspicuus CUSHMAN & WATERS, 1928, Contr. Cushman Lab. Foram. Res., vol. 4, p. 41, pl. 5, fig. 2a,b.

Test elongate, slender, early portion close coiled, planispiral, only slightly compressed of 5 or 6 chambers, later portion straight of 7–8 chambers, not compressed increasing in breadth as added; sutures depressed, distinct; wall finely arenaceous, smoothly finished; aperture nearly circular. Length, 0.70 mm.; breadth, 0.15 mm.; thickness, 0.12 mm.

Dimensions.—Text-figure 6—25, megalospheric: length, 0.51 mm.; diameter of coil



TEXT-FIG. *6*—Virgilian Foraminifera, ×40 (*1, 2*), ×60 (*3–12*), and ×80 (*13–33*).

0.11 mm.; diameter of final chamber, 0.10 mm. Text-figure 6—24 microspheric: length, 0.50 mm.; width, 0.12 mm.; coil, 0.08 mm.

Occurrence.—In Kansas this species was found only in the Kereford member of the Oread limestone. Cushman & Waters found it in Canyon beds in Texas, 110 feet below the Adams Branch limestone.

Remarks.—The Texas forms described are about 25 percent larger than the Kansas forms, but otherwise appear to be the same.

AMMOBACULITES MAGNIGRANULUS
Ireland, n. sp.
Text-fig. 6—26,27

Test planispiral, early portion very small and indistinct, linear portion with 5 or 6 angular irregular poorly defined chambers, all sutures indistinct and irregular; walls thick, composed of large angular quartz sand with much cement; surface rough and angular; aperture in the center of the last chamber.

Dimensions.—Holotype, Text-figure 6—27: length, 0.39 mm.; diameter of coil, 0.11 mm.; average width of chambers, 0.10 mm.

Occurrence.—Holotype in Curzon member of the Topeka limestone (Coll. B13), also found in Avoca member of Lecompton limestone.

Remarks.—The large angular sand grains are many times larger than the grains used by any other species of *Ammobaculites* observed. The indistinct sutures logically result from the use of such large grains. Test-figure 6—26 is believed to be the microspheric form.

Holotype.—U.S.N.M., P2047

AMMOBACULITES MINUTUS Waters, 192
Text-fig. 6—17

Ammobaculites minutus WATERS, 1927, Jour. Paleont., vol. 1, p. 133, pl. 22, fig. 3a,b.

Test small, planispiral in the early portion, later rectilinear, periphery rounded, very slightly umbilicate, chambers in the early coiled portion with eight usually making up the coil, three or four in the rectilinear series, distinct, very slightly inflated; sutures distinct, only slightly depressed; wall finely arenaceous, the sand grains with but little cement, exterior smoothly finished; aperture small, circular, terminal, with evidence of a slight neck; color, white. Diameter of coiled portion, 0.3 mm.; diameter of final chamber, 0.2 mm.; length, 0.6 mm.

Dimensions.—Length, 0.30 mm.; diammeter of coil, 0.12 mm.; diameter of final chamber, 0.09 mm.

Occurrence.—Identified only in the Kereford member of Oread limestone, where it is fairly common. Waters found this species in the Dornick Hills formation of the Ardmore basin in Oklahoma, and Plummer (1945) found it in the Smithwick and lower Strawn in central Texas.

Remarks.—The Kansas specimens of *Ammobaculites* are about half the size of the Ok-

EXPLANATION OF TEXT-FIG. 6

1, 2—Ammovertella labyrintha Ireland, n. sp. Large masses of *Ammovertella* tubes 6 to 10 or more layers thick.
3-7—Ammovertella prodigalis Ireland, n. sp.
3, bottom view, sinuous early part and extended late stage.
4, bottom view of overlapping tests showing extended tubes.
5, bottom view of extended tube and its return to initial area with part of tube unattached.
6, holotype, both bottom and top shown because late stage has bent back over and around edge of object of attachment.
7, bottom view, very simple early stage and extended late stage.
8-12—Ammovertella primaparva Ireland, n. sp.
8, 9, very small early stage with late part missing, bottom view.
10, holotype, bottom view, early and late stage shown.
11, bottom view of early stage only.
12, bottom view of small delicate form showing early and late stages.
13-16—Ammobaculites gracilis Waters. *13*, microspheric form.
17—Ammobaculites minutus Waters.
18-20—Ammobaculites nitidus Waters.
21-23—Ammobaculites parallelus Ireland, n. sp. *22*, probably microspheric form.
24, 25—Ammobaculites inconspicuus Cushman & Waters. *24*, microspheric form; fig. *25*, megalospheric form.
26, 27—Ammobaculites magnigranulus Ireland, n. sp. *27*, holotype; *26*, probably microspheric form.
28, 29—Ammobaculites spirans Cushman & Waters.
30-33—Ammobaculites stenomecus Cushman & Waters.

lahoma and Texas forms. Such is true for most of the other genera of Foraminifera in Kansas.

AMMOBACULITES NITIDUS Waters, 1928
Text-fig. 6—18–20

Ammobaculites nitidus WATERS, 1928, Jour. Paleont., vol. 1, p. 274, pl. 42, fig. 15a,b.

Test small, rough, with early portion coiled, later portion uncoiled in rectilinear series; five chambers in coiled, and five chambers in uncoiled portion; sutures moderately depressed; wall roughly arenaceous, sand grains with little siliceous cement; aperture circular, central, and terminal. Length of holotype, 1.00 mm.; diameter of coil, 0.32 mm.; diameter of uncoiled portion, 0.26 mm.

Dimensions.—Length, 0.30 to 0.40 mm.; diameter of coil, 0.12 mm.; diameter of final chamber, 0.10 to 0.12 mm.

Occurrence.—Very abundant in the Kereford member of Oread limestone, also found in the Avoca member of the Deer Creek formation (Coll. B8), and the Sheldon member of the Topeka formation (Coll. B14). Waters found this species in the Canyon group below the Ranger limestone in central Texas.

AMMOBACULITES PARALLELUS Ireland, n. sp.
Text-fig. 6—21–23

Test elongate, slender, early portion of 5 or 6 chambers close coiled, planispiral, later portion generally straight, 7 or 8 rectilinear inflated chambers all about the same size with parallel sides; sutures distinct, depressed; wall of medium to coarse quartz silt well cemented; surface rough but uniform; aperture circular at end of chamber.

Dimensions.—Length of holotype, Text-figure 6—23: 0.56 mm.; diameter of coil, 0.13 mm.; diameter of chambers, 0.11 mm. Text-figure 6—22, microspheric form: length, 0.56 mm.; diameter of coil, 0.10 mm.

Occurrence.—This species is abundant, but was found only in the Kereford member of the Oread limestone (Coll. A4).

Remarks.—This is a species with many rectilinear chambers of about the same size giving an upper portion with essentially parallel sides. The Kansas specimens for this new species are very different from the large number of other *Ammobaculites* found, especially in the Kereford limestone member, and fit no published description. *A. inconspicuus* Cushman & Waters may also be very long, but its surface is smoother, grains smaller, and chambers increase in diameter. *A. rectum* (H. B. Brady) has a long test, smooth finish, and gently tapering test. Harlton (1927a, p. 20) describes *A. rectum* from Texas, but the Kansas specimens do not fit the description. *A. spirans* Cushman & Waters may be elongate but the chambers are joined at an angle and are not rectilinear.

Holotype.—U.S.N.M., P2048

AMMOBACULITES SPIRANS Cushman & Waters, 1927
Text-fig. 6—28,29

Ammobaculites spirans CUSHMAN & WATERS, 1927, Contr. Cushman Lab. Foram. Res., vol. 3, p. 149, pl. 26, fig. 10.

Test elongate, slender, the early chambers planispirally coiled, later chambers uncoiled but somewhat twisted in their development, so that an irregular biserial form is taken on in some parts of the uncoiled portion; wall arenaceous with a large proportion of cement, surface somewhat roughened; aperture rounded, terminal. Length of holotype, 0.70 mm.; breadth, 0.15 mm.

Dimensions.—Text-figure 6—28; length, 0.41 mm.; diameter of coil, 0.12 mm.; diameter of last chamber, 0.10 mm.

Occurrence.—A few forms occur in the Kereford member of the Oread formation from Coll. A4. The species was found in Texas above the Thurber coal in the upper Strawn by Cushman & Waters.

AMMOBACULITES STENOMECUS Cushman & Waters, 1928
Text-fig. 6—30–33

Ammobaculites stenomecus, CUSHMAN & WATERS, 1928, Contr. Cushman Lab. Foram. Res., vol. 4, p. 59, pl. 5, fig. 1a,b.

Test small, slender, early portion compressed, close coiled, of few chambers, later portion straight, of 4 or 5 chambers, also compressed, sides nearly parallel; sutures but slightly depressed; wall coarsely arenaceous for the size of the test, roughened on the surface; aperture narrow, elliptical. Length, 0.60.; breadth, 0.20 mm.; thickness, 0.10 mm.

Dimensions.—Length, 0.25 to 0.36 mm.; diameter of coil, 0.09 to 0.12 mm.; diameter of last chamber, 0.10 to 0.12 mm.

Occurrence.—Very abundant in the Kereford member of the Oread, also found in

Avoca member of Lecompton formation (Coll. B8), the Rock Bluff member of Deer Creek formation, Curzon and Du Bois members of Topeka formation, and Burlingame and Grandhaven limestones of the Wabaunsee group. Cushman & Waters found this species in central Texas in the Graham formation of the Cisco group just below the Gunsight limestone. Plummer (1945) found it in Strawn shales in the Llano area. Warthin (1930, p. 30) found the species in the Holdenville shale of eastern Oklahoma.

Remarks.—The Kansas specimens are about one-half the size of those described from Texas. The description of Plummer (1945, p. 236) should be consulted for details and special comments. This is the most common species of *Ammobaculites* in the Virgilian of Kansas. It is distinguished from *A. nitidus* by the roughness of the surface and the smaller size.

Family TEXTULARIIDAE d'Orbigny, 1846
Subfamily TEXTULARIINAE d'Orbigny, 1846
Genus TEXTULARIA Defrance, 1824

TEXTULARIA BUCHERI Ireland, n. sp.
Text-fig. 7—1,2

Test free, rapidly tapering, small; biserial chambers rapidly enlarging, wider than high; sutures indistinct slightly depressed; wall composed of fine to coarse quartz particles; surface very rough and irregular due to angular particles; aperture at basal margin of last chamber.

Dimensions.—Holotype, Text-figure 7—1: height 0.28 mm.; width, 0.18 mm.; text-figure 7–2: height, 0.18 mm.; width, 0.11 mm. Angle of apex, 42 degrees.

Occurrence.—Very common in Kereford member of Oread limestone (holotype from Coll. A4) and in Avoca member of Lecompton limestone (Coll. B8). Also present in Burlingame limestone and common in Reading limestone.

Remarks.—This species is recognizable by its small size, wedge-like test (ratio of width to length, 0.60:1), rough surface and indistinct chambers and sutures.

Holotype.—U.S.N.M., P2049

TEXTULARIA ELSIAE Ireland, n. sp.
Text-fig. 7—3–5

Test free, very small, almost as wide as long; late chambers inflated, globular, generally not more than 6 distinct ones, initial chambers crowded giving a blunt end to test; sutures depressed and distinct; wall of medium to fine quartz particles; surface smooth; aperture a wide low arch at base of last chamber.

Dimensions.—Holotype, Text-figure 7—5, from Rock Bluff limestone: height, 0.26 mm.; width, 0.23 mm.; fig. 1b, width, 0.16 mm. Ratio of width to length, 0.72 to 0.88:1, angle of taper 45 degrees.

Occurrence.—Present in Kereford member of Oread limestone, very common in Avoca member of Lecompton limestone (Coll. B8) and Rock Bluff member of Deer Creek limestone, abundant in Curzon and present in Sheldon members of Topeka limestone. Present in the Elmont limestone of the Wabaunsee group.

Remarks.—This is a very small species. The holotype is the largest specimen seen. It differs from *T. bucheri* by having a blunt end, more rapidly enlarging and inflated chambers, distinct sutures and smooth surface.

Holotype.—U.S.N.M., P2050

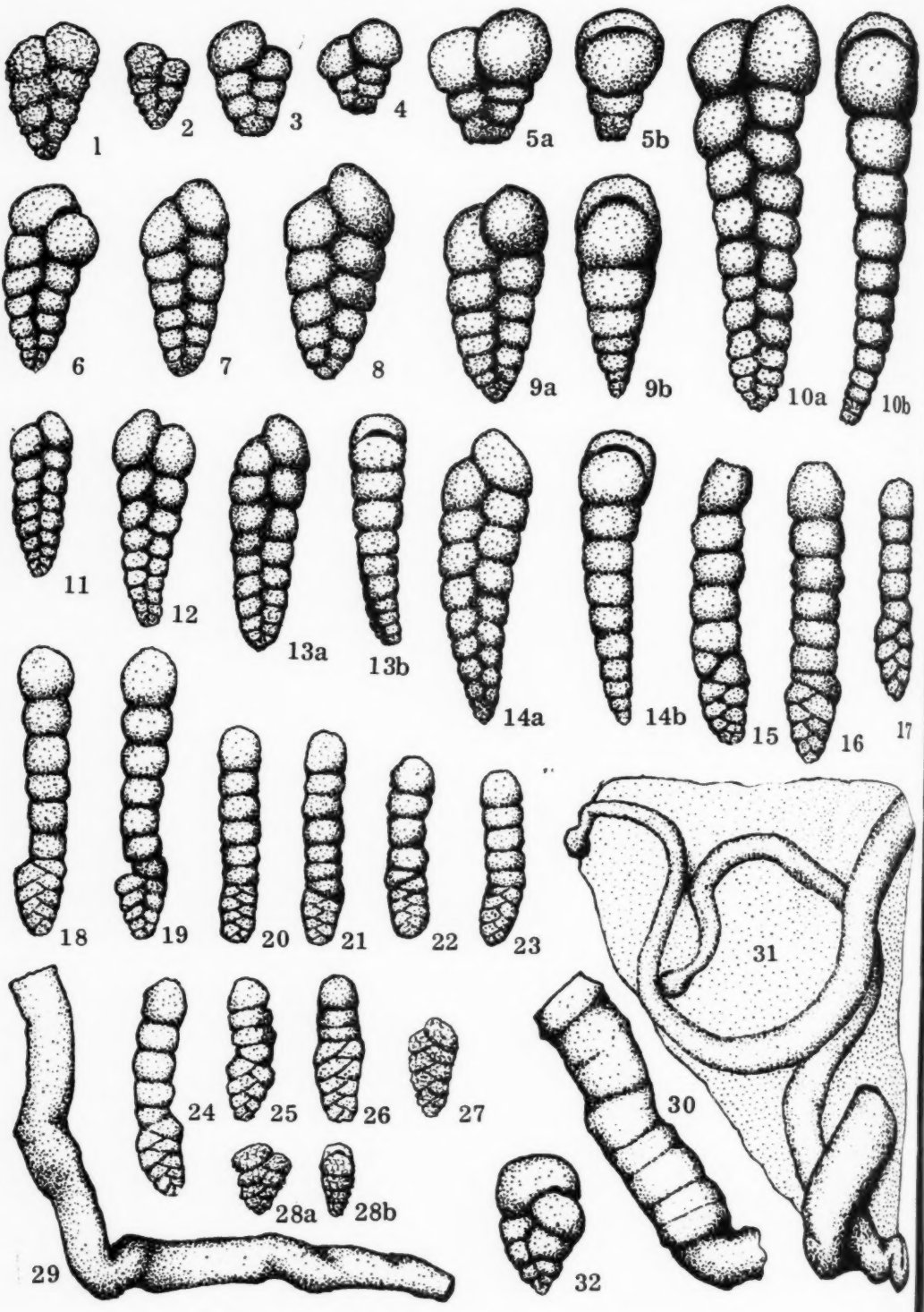
TEXTULARIA EXIMIA Eichwald, 1860
Text-fig. 7—6–9

Textularia eximia EICHWALD, 1860, Lethaea Rossica, vol. 1, p. 355, pl. 22, fig. 19a–d. H. B. BRADY, 1876, Pal. Soc. Mono. 30, p. 132, pl. 10, fig. 27–29. CUSHMAN & WATERS, 1930, Univ. Texas Pub. 3019, p. 53, pl. 4, fig. 9–11.

Test free, tapering, nearly as thick as wide; 12 to 14 inflated chambers enlarging uniformly, sutures distinct and depressed, essentially horizontal; wall of medium to fine quartz grains well cemented; surface smooth but grains stand out distinctly; aperture an arch at the base of the last chamber.

Dimensions.—Text-figure 7—9: length, 0.41 mm.; width, 0.20 mm.; thickness, 0.17 mm. Ratio of width to length on several specimens, 0.50. Ratio of thickness to width, 0.80. Average angle of taper 25 degrees.

Occurrence.—Very common in Avoca member of Lecompton limestone in Colls. A8 and B8; very common in Rock Bluff member of Deer Creek formation in Colls. A10 and B10; common in Sheldon member of Topeka limestone (Coll. B14); common in



TEXT-FIG. 7—Virgilian Foraminifera, ×80; except *29–31*, ×40.

Church limestone of the Wabaunsee group. Cushman & Waters (1930) identify *T. eximia* from below the New Castle coal and in the South Bend shale of the Cisco group in central Texas. H. B. Brady (1876) describes the species from the Carboniferous of England, and Eichwald (1860) originally described it from the Carboniferous of Russia.

Remarks.—This species is very distinct from *T. virgilensis*. It is much shorter, proportionately wider, and has fewer chambers. The taper angle is 25 degrees while that for *T. virgilensis* is 13 to 16 degrees. The ratio of width to length is 0.50, whereas *T. virgilensis* is about 0.35. The surface of *T. eximia* is less rough and the test is straight and uniform, rarely with any twist or curvature. Specimens are abundant and specific differences well displayed.

The original figures of Eichwald are poor, but those by H. B. Brady are excellent. The Kansas forms are one-third the size of the European forms described by Brady and a little more than one-half the size of the Texas forms, but otherewise fit the description well. The figures of Cushman & Waters (1930, pl. 4, fig. 9,19 [not fig. 11]) are almost identical with the Kansas forms.

TEXTULARIA VIRGILENSIS
Ireland, n. sp.
Text-fig. 7—10–14

Test free, very long, tapering, sometimes curved or twisted, 16 to 24 somewhat inflated biserial chambers; sutures sharply but not greatly depressed, distinct, almost horizontal; walls of medium quartz particles well cemented; surface somewhat rough, aperture a very low broad arch at the base of the last chamber.

Dimensions.—Holotype, Text-figure 7—14: length, 0.55 mm.; width, 0.19 mm.; thickness, 0.14 mm. The specimen shown as Text-figure 7—10 is unusually large with a length of 0.76 mm. and a width of 0.26 mm. Other figures range from 0.31 mm. to 0.48 mm. in length and 0.11 to 0.18 mm in width. The ratio of width to length for a dozen specimens consistently ranges from 0.32 to 0.38. The angle of taper ranges from 13 to 16 degrees.

Occurrence.—Abundant in Toronto (Colls. A1 and B1), present in Plattsmouth and very abundant in Kereford members of Oread limestone; present in Beil (Coll. B7) and Avoca (Coll. B8) members of Lecompton limestone; abundant in Rock Bluff (Colls. A10 and B10) and present in Ervine Creek members of Deer Creek formation; present in Curzon (Coll. A13) and Sheldon (Coll. B14) members of Topeka limestone. It is abundant to common in the Church, Burlingame, Wakarusa, and Reading limestones of the Wabaunsee group. Holotype is from Kereford limestone from Coll. B7.

Remarks.—The specimen from Coll. B7 shown as Text-figure 7—10 is abnormally larger than most of the Kansas forms,

EXPLANATION OF TEXT-FIG. 7

1,2—Textularia bucheri Ireland, n. sp.
3-5—Textularia elsiae Ireland, n. sp. *5b*, side view.
6-9—Textularia eximia Eichwald. Fig. *9b*, side view.
10-14—Textularia virgilensis Ireland, n. sp.
10a, front view; *10b*, side view, extra large size.
11,12, smallest sizes found.
13a, front view; *13b*, side view.
14a, front view; *14b*, side view, holotype.
15-17—Bigenerina elongata Ireland, n. sp. *16*, holotype.
18,19—Bigenerina virgilensis Ireland, n. sp. *18*, holotype.
20-23—Bigenerina perexigua Plummer. Typical well-developed forms.
24-28—Bigenerina ciscoensis Cushman & Waters.
24-26, typical forms.
27, young biserial stage, not a broken form.
28a, young biserial form; *28b*, side view showing textularian type of aperture.
29-31—Apterrinella grahamensis (Harlton)
29,30, typical tubes of the late stages, both silicified from former calcareous state.
31, two well-developed silicified forms on silicified shell fragment, formerly were calcareous. Easily confused with *Tolypammina*, which are arenaceous.
32—Verneuilina virgilensis Ireland, n. sp.

though there was one other which was intermediate to the average size. The chief characteristics of this species are the very long narrow test with a large number of chambers, the very low taper angle, and the rough surface.

Holotype.—U.S.N.M., P2051

Genus BIGENERINA d'Orbigny, 1826
BIGENERINA CISCOENSIS Cushman & Waters, 1928
Text-fig. 7—24–28

Bigenerina ciscoensis CUSHMAN & WATERS, 1928, Contrib. Cushman Lab. Foram. Res., vol. 4, p. 63, pl. 8, fig. 5.

Test small, elongate, the early portion compressed and tapering, the chambers biserial, later portion with the sides nearly parallel, of a few, 3–5, uniserial chambers in a rectilinear series; early chambers broad and low, increasing gradually in height as added, later uniserial chambers nearly as high as broad; sutures distinct, only slightly depressed; wall rather coarsely arenaceous but the angular grains neatly fitted and the surface fairly smooth, firmly cemented; aperture large for the size of the chamber, elliptical, terminal. Length, 0.45–0.50 mm.; breadth, 0.12–0.15 mm.

Dimensions.—Length, 0.25 to 0.40 mm.; width, of last chamber, 0.10 mm.; width of biserial portion, 0.12 mm. Text-figure 7—27: length, 0.19 mm.; width, 0.10 mm.

Occurrence.—Abundant in the Toronto member (Colls. A1 and B1) and present in the Plattsmouth member of the Oread limestone; found in Hartford, Curzon, and Sheldon members of Topeka formation; Wakarusa limestone and Reading limestone. Cushman & Waters (1928d) found the species in the Cisco below the Gunsight limestone and Warthin (1930) found in it the Holdenville shale in eastern Oklahoma.

Remarks.—The distinguishing characteristic of *B. ciscoensis* is the inflation of one or both sides of the termination of the biserial portion and the small number of uniserial chambers.

Text-figures 7—27,28 are young tests of *Bigenerina*, probably *B. ciscoensis*. At first they were thought to be *Textularia* for they have all the characteristics of that genus, especially the arched aperture. However, the arched aperture at the basal margin of the chamber is normal to the biserial stage of *Bigenerina*. The size of the specimens, the aggregation of rough quartz particles, and the close association with many other *Bigenerina* indicate that they are the young biserial part of that genus. Some of them could be broken adult tests, but there are many lacking evidence of breakage.

BIGENERINA ELONGATA Ireland, n. sp.
Text-fig. 7—15–17

Test large and long, biserial portion with 8 to 10 chambers; 5 or 6 uniserial chambers in rectilinear series, inflated, broader than wide, not much change in diameter at juncture with biserial portion; sutures slightly depressed, not well defined; walls of medium to coarse quartz particles; surface rough; aperture central on the last chamber.

Dimensions.—Holotype, Text-figure 7–16; length, 0.57 mm.; width, 0.11 mm.

Occurrence.—Abundant in Toronto member (Coll. B1) and present in Kereford member of Oread limestone and Hartford and Sheldon members of Topeka limestone (Coll. B14). In the Wabaunsee group the Wakarusa limestone contains the species. Holotype from Toronto member.

Remarks.—This is the largest and most robust species of *Bigenerina* found in the Virgilian beds. It is much larger than *B. ciscoensis* and has more chambers. The uniserial chambers do not taper as in *B. virgilensis* and the inflation at the top of the biserial series is not prominent.

Holotype.—U.S.N.M., P2052

BIGENERINA PEREXIGUA Plummer, 1945
Text-fig. 7—20–23

Bigenerina perexigua PLUMMER, 1945, Univ. Texas Pub. 4401, p. 243, pl. 16, fig. 19,20.

This very minute, slender test is rather coarse considering its size. The globular proloculum is followed by eight to ten gradually enlarging biserial chambers. On some tests two succeeding chambers are loosely biserial before the regular sequence of as many as seven uniserial chambers is added. Sutures are sharply, but not deeply, incised. The shell wall is thin and insoluble in acid and is composed of quartz grains so neatly fitted, that the surface is not sharply rugose, though granules are rather large for the delicate build of the test. The aperture is a terminal round opening on the somewhat constricted final chamber.

A common length of test bearing five uniserial chambers is about 0.4 mm., and the breadth of the uniserial portion is almost uniformly 0.09 mm. The length of the biserial stage averages about 0.15 mm.

Dimensions.—Length, 0.32–0.40 mm.; width, 0.08 mm.

Occurrence.—Abundant in the Toronto member of Oread limestone (Colls. A1 and B1), and present in Avoca member of Deer Creek (Coll. B8), Sheldon member of Topeka limestone (Coll. B14), and in the Burlingame limestone.

Remarks.—The distinguishing characteristics are the lack of a constriction where the biserial portion ends, the uniform width, and the contrast of the oversize granules of the test with the delicate streamlined construction and appearance.

Plummer found the species in the Strawn of Kimble County in central Texas and farther to the north in the Mineral Wells formation at Mineral Wells, Texas.

BIGENERINA VIRGILENSIS Ireland, n. sp.
Text-fig. 7—18,19

Test very long and slender, larger than most other associated forms; biserial portion small, sharply set off from the uniserial portion by a distinct inflation on one side; 6 uniserial chambers in rectilinear series, later ones almost equidimensional, younger chambers increase slightly in size; sutures well defined and slightly depressed; walls of fine quartz particles well cemented; surface smooth, aperture at center of last chamber.

Dimensions.—Holotype, Text-figure 7—18: length, 0.55 mm.; width of last chamber, 0.10 mm.; maximum width across biserial portion, 0.09 mm., length of biserial portion, 0.15 mm.

Occurrence.—Found in Rock Bluff and Ervine Creek members of Deer Creek formation, Church, Wakarusa, and Reading limestones. Holotype is from Wakarusa (Coll. A20).

Remarks.—The large number of slightly tapering uniserial chambers, the length, and the distinct separation of the biserial part are the chief distinguishing features. *B. elongata* has chambers larger than this species, but they do not taper and the biserial portion is not marked off distinctly.

Holotype.—U.S.N.M., P2053

Family VERNEUILINIDAE Cushman, 1911
Genus VERNEUILINA d'Orbigny, 1840
VERNEUILINA VIRGILENSIS Ireland, n.sp.
Text-figure 7—32

Test free, triserial, small; chambers distinct, inflated, rapidly enlarging; sutures distinct and depressed; walls of very fine uniform quartz particles clearly visible; surface smooth; aperture a wide arch at the base of the last chamber.

Dimensions.—Height, 0.28 mm.; greatest width, 0.20 mm.

Occurrence.—Du Bois member of Topeka limestone, holotype from Coll. B15.

Remarks.—Whole specimens are rare. The one shown is well developed and clearly a *Verneuilina*. I can find no existing record of this genus prior to the Jurassic. It has not been recorded in any of the literature examined on Paleozoic arenaceous forms and the species is therefore believed to be the oldest known *Verneuilina*.

Holotype.—U.S.N.M., P2054

Family OPHTHALMIDIIDAE
Subfamily CORNUSPIRINAE
Genus APTERRINELLA Cushman & Waters, 1928
APTERRINELLA GRAHAMENSIS (Harlton) 1928
Text-fig. 7—29–31

Tolypammina grahamensis HARLTON, 1928, Jour. Paleont., vol. 1, p. 305, pl. 52, fig. 1.
Apterrinella grahamensis CUSHMAN, 1928, Contr. Cushman Lab. Foram. Res., vol. 4, p. 68, pl. 9, fig. 1–4. CUSHMAN & WATERS, 1930, Univ. Texas Pub. 3019, p. 62, pl. 5, fig. 6–9.

Cushman & Waters description:

Test attached to mollusc shells or other objects, consisting of a slightly compressed subspherical proloculum and tubular second chamber, the proloculum smooth and the early part of the tubular chamber in the microspheric form, later the surface strongly and irregularly reticulate, the side of the tubular chamber spreading out over the surface of attachment in a thin flange, in the megalospheric form the large proloculum smooth but the reticulation of the wall beginning almost immediately after the proloculum; wall calcareous, imperforate, blueish white in the early stages; aperture semicircular at the open end of the tube. Length of adult specimens, 10.00 mm. or more.

Dimensions.—The longest of the two forms shown on Text-figure 7—31 is 1.90 mm. long and the largest tube diameter is 0.30 mm. The proloculum of the right hand form is 0.10 mm. in diameter.

Occurrence.—A large number of silicified specimens of this species were found in the lower few feet of the Kereford limestone (Coll. A4).

Remarks.—The specimens have the typical characteristics of *Apterrinella* as described by Cushman & Waters. Essentially

identical forms are associated in the same beds but they are composed of distinct quartz sand grains, and belong to *Tolypammina* (*T. rugosa*, n. sp.). The general form of the Kansas specimens and the original figure of Harlton resembles *Tolypammina*, but the apparent continuous attachment and flattened undersurface suggests *Ammovertella*. Cushman (1928) discusses why *T. grahamensis* should be called *Apterrinella grahamensis*. The large tubes replaced by silica look like free tubes created by *Tolypammina*, but they are referred to *Apterrinella* because they are not composed of aggregated quartz sand grains.

REFERENCES

BRADY, H. B., 1876, A monograph of Carboniferous and Permian Foraminifera (exclusive of Fusulina): Pal. Soc. Mono. 30, 166 p.

COOPER, C. L., 1947, Role of micropaleontology in interregional correlations: Jour. Geol., vol. 55, p. 261–270.

CUSHMAN, J. A., 1928, The microspheric and megalospheric forms of *Apterrinella grahamensis:* Cushman Lab. Foram. Res., vol. 4, p. 68–69.

——, 1930, Notes on early Paleozoic Foraminifera: Cushman Lab. Foram. Res., vol. 6, p. 43–44.

——, 1935, Paleozoic Foraminifera and their relationship to modern faunas and to their environment: Jour. Paleont., vol. 9, p. 284–287.

——, 1950, Foraminifera, their classification and economic use: 4th ed., Harvard Univ. Press.

CUSHMAN, J. A., & WATERS, J. A., 1927a, Pennsylvanian Foraminifera from Michigan: Contr. Cushman Lab. Foram. Res., vol. 3, p. 107–110.

——, & ——, 1927b, Arenaceous Paleozoic Foraminifera from Texas: Contrib. Cushman Lab. Foram. Res., vol. 3, p. 146–155.

——, & ——, 1928a, The development of *Climacammina* and its allies in the Pennsylvanian of Texas: Jour. Paleont., vol. 2, p. 119–132.

——, & ——, 1928b, Upper Paleozoic Foraminifera from Sutton County, Texas: Jour. Paleont., vol. 2, p. 358–371.

——, & ——, 1928c, Some Foraminifera from the Pennsylvanian and Permian of Texas: Contr. Cushman Lab. Foram. Res., vol. 4, p. 31–55.

——, & ——, 1928d, Additional Cisco Foraminifera from Texas: Contrib. Cushman Lab. Foram. Res., vol. 4, p. 62–67.

——, & ——, 1930, Foraminifera of the Cisco group: Univ. Texas Pub. 3019, p. 22–81.

ELLIS, B. F., & MESSINA, ANGELINA R., 1940–1955, Catalogue of Foraminifera: Amer. Mus. Nat. Hist., New York.

GALLOWAY, J. J., 1933, A manual of Foraminifera: Principia Press.

GALLOWAY, J. J., & HARLTON, BRUCE, 1928, Some Pennsylvanian Foraminifera of Oklahoma with special reference to the genus *Orabias:* Jour. Paleont., vol. 2, p. 338–357.

——, & ——, 1930, Endothyranella, a genus of Carboniferous Foraminifera: Jour. Paleont., vol. 4, p. 24–28.

——, & RYNIKER, CHARLES, 1930, Foraminifera from the Atoka formation of Oklahoma: Okla. Geol. Survey, Circ. 21, 27 p.

HARLTON, BRUCE, 1927a, Some Pennsylvanian Foraminifera in the Glenn formation of southern Oklahoma: Jour. Paleont., vol. 1, p. 15–27.

——, 1927b, Pennsylvanian Foraminifera of Oklahoma and Texas: Jour. Paleont., vol. 1, p. 305–310.

——, 1933, Micropaleontology of the Pennsylvanian Johns Valley shale of the Ouachita Mountains, Oklahoma and its relationship to the Mississippian Caney shale: Jour. Paleont., vol. 7, p. 3–11.

IRELAND, H. A., 1939, Devonian and Silurian Foraminifera from Oklahoma: Jour. Paleont., vol. 13, p. 190–202.

MOORE, R. C., 1936, Stratigraphic classification of the Pennsylvanian rocks of Kansas: State Geol. Survey Kan., Bull. 22, p. 2–34.

——, 1949, Divisions of the Pennsylvanian system in Kansas: State Geol. Surv. Kan., Bull. 83, 200 p.

MOREMAN, W. L., 1930, Arenaceous Foraminifera from Ordovician and Silurian limestones of Oklahoma: Jour. Paleont., vol. 4, p. 42–59.

PLUMMER, HELEN J., 1930, Calcareous Foraminifera in the Brownwood shale near Bridgeport, Texas: Univ. Texas Pub. 3019, p. 5–21.

——, 1945, Smaller Foraminifera in the Marble Falls, Smithwick, and lower Strawn strata around the Llano Uplift in Texas: Univ. Texas. Pub. 4401, p. 209–271.

ROTH, ROBERT, & SKINNER, JOHN, 1930, Fauna of the McCoy formation Pennsylvanian of Colorado: Jour. Paleont., vol. 4, p. 332–352.

WARTHIN, A. S., 1930, Micropaleontology of the Wetumka, Wewoka, and Holdenville formations: Okla. Geol. Surv., Bull. 53, 94 p.

WATERS, J. A., 1927a, A group of Foraminifera from the Dornick Hills formation of the Ardmore basin: Jour. Paleont., vol. 1, p. 129–133.

——, 1927b, A group of Foraminifera from the Canyon division of the Pennsylvanian formations in Texas: Jour. Paleont., vol. 1, p. 271–275.

JOURNAL OF PALEONTOLOGY, VOL. 30, NO. 4, P. 865–868, PL. 97, JULY 1956

NOTES CONCERNING A SENONIAN VALVULINERIAN

R. W. HARRIS AND C. L. McNULTY, JR.
Oklahoma University, Norman, and Continental Oil Company, Roswell, New Mexico

ABSTRACT—*Valvulineria cretacea* (Carsey) and *V. depressa* (Alth) from Senonian strata of the United States Gulf Coastal Plain are considered synonyms of *V. lenticula* (Reuss) originally from the Senonian of Europe.

WHILE investigating lower and upper Senonian faunules from outcrops in Texas and Arkansas, the writers discovered information clarifying the relations and taxonomic status of *Valvulineria cretacea* (Carsey) and *V. depressa* (Alth).

The record of the American form long identified as *Gyroidina depressa* (Alth) began with the description of the Texas form, *Rotalia cretacea* Carsey (1926, p. 48, pl. 5, fig. 1a,b). In 1929, Cushman & Church (p. 515, pl. 41, fig. 4–6) described and illustrated the same form from the Cretaceous of California as *Gyroidina depressa*, changing Alth's original genus and assigning Carsey's species to synonymy. Later scientists (see synonymy) discovered the species in Senonian faunas and reported it as *Gyroidina depressa* (Alth), though Berry & Kelley (1929, p. 15, pl. 3, fig. 10–12) reported the eleven to twelve chambered form from the Ripley of Tennessee as *Rotalia beccarii* (Linné) var. *ripleyensis* Berry & Kelley.

In 1943 Cushman & Todd (p. 67, pl. 12, fig. 1a–c) described and illustrated *Valvulineria cretacea* (Carsey) from the Navarro of Texas, again changing the generic assignment and redefining *Rotalia cretacea* Carsey, which had been placed in synonymy with *Gyroidina depressa* (Alth) during the intervening fourteen years. In 1946 Cushman (p. 139) reported *Valvulineria cretacea* (Carsey) from numerous Navarro (and some Taylor) localities of the Gulf Coastal Plain. However, he failed to remove the holotype, *Rotalia cretacea* Carsey, from the synonymy of *Gyroidina depressa* (Alth), presumably an editorial error. From uppermost Taylor equivalents of California, Bandy (1951, p. 504, pl. 74, fig. 1a–c) described and illustrated *Valvulineria cretacea* (Carsey) as uncompressed, flush-chambered, peripherally acute with nine to twelve chambers in the final whorl. Recently Frizzell (1954, p. 123, pl. 18, fig. 36a–c) assigned *Valvulineria cretacea* (Carsey) to synonymy of *Gyroidina depressa* (Alth) and employed for its illustrations the original Cushman & Todd figures (displaying an umbilical flap) of *Valvulineria cretacea* (Carsey).

Originally *Valvulineria cretacea* (Carsey) was distinguished from *Gyroidina depressa* (Alth) by the presence of an umbilical flap, more chambers (ten to fifteen) in the final whorl, less chamber inflation, less compression, and more acute periphery. However, the present writers discovered the umbilical flap more-or-less developed on all specimens involved (see later discussion), and no more than twelve chambers in the final whorl. In addition, it was discovered that specimens of a single faunule displayed sufficient variation in chamber inflation, compression, and peripheral taper to indicate that such differences were not specific. Aside from the aforementioned observations, variation approaching (if not attaining) the diagnostic properties of *Valvulineria cretacea* (Carsey) is displayed by the different specimens of *Gyroidina depressa* (Alth) illustrated by Cushman (1946, pl. 57, fig. 3a–c; pl. 58, fig. 1–4). The Niobrara specimen (*ibid.* pl. 57, fig. 3) listed as *Valvulineria plummerae* Loetterle is actually *Gyroidina depressa* (Alth) (see Loetterle, 1937, pl. 6, fig. 7a–c). Attention is particularly directed to the lack of compression, lack of chamber inflation and lack of peripheral taper of Cushman's Selma specimen (*ibid.*, pl. 58, fig. 4).

Extremes of variation are noticeably more common in faunules from Navarro strata, where the peripherally tapering forms, typical of *Valvulineria cretacea* (Carsey) as defined by Cushman & Todd, are often predominant and the species itself may be abundant. However, even these faunules contain specimens referable to *Gyroidina depressa* (Alth) of Cushman & Church, thus

linking the extreme variants to the latter species (Pl. 97, fig. 1,2,5). Accordingly, it appears from the record and from our own observations that these two types from the Senonian are gradational, some faunules displaying a *Valvulineria cretacea* (Carsey) aspect, more displaying a *Gyroidina depressa* (Alth) aspect, but many defying confident assignment to one or the other alone. Consequently, it appears that there is involved but a single species, whose basic properties are intermediate to both typical *Valvulineria cretacea* (Carsey) and *Gyroidina depressa* (Alth). The combining of these two undeniably similar species results in a distinctive, natural species with a well-established range and eliminates the problem of essentially subjective distinction between two very similar gradational forms.

As previously noted, the writers observed several specimens of *Gyroidina depressa* (Alth) with definite umbilical flap, and many others with apparent flap. On exceptionally well preserved specimens the umbilical flap may be observed to be rather sharply differentiated from the inner margin of the final chamber by its slightly less perforate and more hyaline shell material, which continues into and also characterizes the apertural lip. Consequently, the flap appears as a development attached to the internal side of the final chamber. Although hitherto unmentioned, such flap structure is clearly displayed by specimens typical of *Valvulineria cretacea* (Carsey) from Navarro strata (Pl. 97, fig. 2,5).

Discovery of an umbilical flap on *Gyroidina depressa* (Alth) necessitates reassignment of this species to the genus *Valvulineria* Cushman (1926). Such assignment is much more compatible with the general architecture of *Gyroidina depressa* (Alth), which is, as all descriptions and illustrations denote, an essentially biconvex form with subequal development of involute and evolute faces, rather than a more-or-less plano-convex form, as is characteristic of the genus *Gyroidina* d'Orbigny (1826). Furthermore, it conforms with the evidence of consanguinity of *Gyroidina depressa* (Alth) and *Valvulineria cretacea* (Carsey).

In addition the presence of the umbilical flap dictates specific assignment of both *Valvulineria depressa* (Alth) and its synonym, *Valvulineria cretacea* (Carsey) to *V. lenticula* (Reuss). Judging from the original description, Reuss' species differs from *Rotalia depressa* Alth only in the possession of an umbilical flap. Alth noted the probable consanguinity of *Rotalina depressa* Alth and *Rotalina lenticula* Reuss:

> Diese Species (*Rotalina depressa* Alth) erinnert an *R. lenticula* Reuss Taf. XII, f. 17, mit der sie vielleicht identisch ist. Doch habe ich die zungenförmige Verlängerung der letzen Kammer nicht merken können.

However, Reuss' species (with definite umbilical flap) has priority; consequently, the American form must be identified as his species.

SYSTEMATIC PALEONTOLOGY

Family ROTALIIDAE Cushman, 1915

Genus VALVULINERIA Cushman, 1926

VALVULINERIA LENTICULA (Reuss)

Pl. 97, fig. 1–5

Rotalina lenticula REUSS, 1845, Die Versteinerungen der böhmischen Kreideformation, p. 35, pl. 12, fig. 17a–c.

Rotalina depressa ALTH, 1850, Haidinger's Naturw. Abh., vol. 3, p. 266, pl. 13, fig. 21.

Rotalia cretacea CARSEY, 1926, Univ. Tex., Bull. 2612, p. 48, pl. 5, fig. 7a,b.

Rotalia beccarii (LINNE) var. *ripleyensis* BERRY & KELLEY, 1929, U.S.N.M., Proc., vol. 72, Art. 19, p. 15, pl. 3, fig. 10–12.

Gyroidina depressa CUSHMAN & CHURCH, 1929 Calif. Acad. Sci., Proc., 4th ser., vol. 18, p. 515, pl. 41, fig. 4–6. CUSHMAN, 1946, U. S. Geol. Surv., Prof. Pap. 206, p. 139, pl. 57, fig. 3a–c; pl. 58, figs. 1–4 (see this reference for additional synonymy to 1946); 1949, U. S. Geol. Surv., Prof. Pap. 221-A, p. 9, pl. 4, fig. 12,13; 1949, Md. Dept. Geol. Mines & Water Res., Bull. 2, p. 264, pl. 25, fig. 18a,b. FRIZZELL, 1954, Univ. Tex., Rept. Inves. 22, p. 123, pl. 18, fig. 36a–c.

Gavelinella cretacea BROTZEN, 1942, Sver. Geol. Unders., ser. C, no. 451, Arsb. 36, p. 54.

Valvulineria cretacea CUSHMAN & TODD, 1943, Cushman Lab. Foram. Res., Contr., vol. 19, p. 67, pl. 12, fig. 1a–c. CUSHMAN, 1946, U. S. Geol. Surv., Prof. Pap. 206, p. 138, pl. 57, fig. 8a–c (see this reference for additional synonomy to 1946); 1949, U. S. Geol. Surv., Prof. Pap. 221-A, p. 8 (no illustration); 1949, Md. Dept. Geol. Mines & Water Res., Bull. 2, p. 263, pl. 25, fig. 13a,b. BANDY, 1951, Jour. Paleont., vol. 25, p. 504, pl. 74, fig. 1a–c.

Test trochoid with similar development of involute and evolute surfaces, dextrally or sinistrally coiled, lenticular, peripherally rounded and somewhat compressed to subacute and uncompressed. Umbilicus covered

by a lowly convex plate attached to the ventral side of the inner margin of the final chamber and extending peripherally to form the apertural lip. Chambers nine to twelve in the final whorl, initially flush, becoming slightly inflated terminally. Sutures obscure to distinct and limbate, straight to slightly curved ventrally, strongly curved dorsally. Surface finely perforate; aperture a very low, elongate opening along the base of the final chamber on the ventral surface; diameter 0.25 to 0.50 mm., thickness 0.10 to 0.25 mm.

Hypotype No. KArk 101; maximum diameter 0.29 mm.; and Hypotype No. KArk 102; maximum diamater 0.38 mm.; minimum diameter 0.30 mm.; thickness 0.15 mm.; and Hypotype No. KArk 103; maximum diameter 0.32 mm., from Arkadelphia formation in roadside cut an old highway through Military Proving Grounds 6.7 mi. northwest of Hope, Arkansas. Hypotype No KBon 101; maximum diameter 0.30 mm.; and Hypotype No. KBon 102; maximum diameter 0.35 mm.; minimum diameter 0.30 mm.; thickness 0.17 mm., from Bonham formation, 2.5 mi. east of Bonham, Texas, in road cut on U. S. Highway 82, at crest of first hill east of Bois d'Arc Creek.

As redefined, *Valvulineria lenticula* (Reuss) is a very distinctive species whose closest affinity of comparable stratigraphic range is *Valvulineria plummerae* Loetterle, a similar but turgid form which can be distinguished by its subglobular shape. Although not normally a numerically important member of faunule populations, *Valvulineria lenticula* (Reuss) occurs throughout Senonian strata of the Gulf Coastal Plain and displays broad geographic distribution elsewhere, being recorded from the Senonian of California, Kansas, Canada, South America and western Europe.

In 1942 Brotzen (p. 54) assigned *Rotalia cretacea* Carsey to the genus *Gavelinella* Brotzen, 1942. However, this genus, like the very similar *Pseudovalvulineria* Brotzen, 1942, possesses an open umbilicus and secondary umbilical aperture whereas, the umbilicus of *Valvulineria lenticula* (Reuss) is covered by an umbilical flap, and no secondary umbilical aperture was observed. One may rightfully question the taxonomic significance of an umbilical flap; however the lack of this flap is a primary basis for the erection of *Gavelinella* Brotzen and *Pseudovalvulineria* Brotzen, and its presence is therefore justification for excluding *Valvulineria lenticula* (Reuss) from these genera. Moreover, recent studies (Gandolfi, 1955, p. 81) relate *Pseudovalvulineria* Brotzen to the genus *Globotruncana* Cushman, 1926. If true, it would appear to follow that *Gravelinella* Brotzen is also related to the globotruncane, rather than the valvulinerian-discorbine-gyroidine group. It is possible that Brotzen was misled by the fact that Carsey did not detect the umbilical flap and chose a holotype on which the flap was apparently broken away.

BIBLIOGRAPHY

ALTH, A. V., 1849, Geognostisch-palaeontologische Beschreibung der nächsten Umbegung von Lemberg: Haidinger's Naturw. Abh., vol. 3.

BANDY, C. L., 1951, Upper Cretaceous foraminifera from the Carlsbad area, San Diego, California: Jour. Paleont., vol. 25, no. 4, p. 488–513, pl. 72–75.

BERRY, WILLARD, & KELLEY, LOUIS, 1929, The foraminifera fauna of the Ripley formation of Coon Creek, Tenn.: U. S. Nat. Mus., Proc., vol. 76, art. 19, 20 p., 3 pl.

BROTZEN, F., 1942, Die Foraminiferengattung Gavelinella nov. gen. und die Systematik der Rotaliiformes: Sver. Geol. Unders., ser. C, no. 451, Arsb. 36, p. 1–60, pl. 1.

CARSEY, D. O., 1926, Foraminifera of the Cretaceous of central Texas: Univ. Tex., Bull. 2612, 56 p. 8 pl.

CUSHMAN, J. A., 1931a, Preliminary report on foraminifera of Tennessee: Tenn. Div. Geol., Bull. 41, 112 p., 13 pl.

——, 1931b, The foraminifera of the Saratoga chalk: Jour. Paleont., vol. 5, p. 297–315, pl. 34–36.

——, 1932, The foraminifera of the Annona chalk: Jour. Paleont., vol. 6, p. 330–345, pl. 50–51.

——, 1936, Geology and Paleontology of the Georges Bank canyon, part 4, Cretaceous and late Tertiary foraminifera: Geol. Soc. Amer., Bull., vol. 47, p. 413–440, pl. 1–5.

——, 1944a, The foraminiferal fauna of the type locality of the Pecan Gap chalk: Cush. Lab. Foram. Res., Contr., vol. 20, pt. 1, p. 1–13, pl. 1–3.

——, 1944b, Foraminifera of the lower part of the Mooreville chalk of the Selma group of Mississippi: Cush. Lab. Foram. Res., Contr., vol. 20, pt. 4, p. 83–96, pl. 13,14.

——, 1946, Upper Cretaceous foraminifera of the Gulf Coastal region of the United States and adjacent areas: U. S. Geol. Surv., Prof. Pap. 206, 160 p., 66 pl.

——, 1947, A foraminiferal fauna from the Santa

Anita formation of Venezuela: Cush. Lab. Foram. Res., Contr., vol. 23, pt. 1, p. 1–18, pl. 1–4.

——, 1949a, The foraminiferal fauna of the Upper Cretaceous Arkadelphia marl of Arkansas: U. S. Geol. Surv., Prof. Pap. 221-A, 19 p., 4 pl.

——, 1949b, Cretaceous and Tertiary subsurface geology of three deep test wells on the eastern shore of Maryland: Md. Dept. Geol. Mines & Water Res., Bull. 2, p. 213–268, pl. 15–26.

——, & CHURCH, C. D., 1929, Some Upper Cretaceous foraminifera from near Coalingua, California: Calif. Acad. Sci., Proc., ser. 4, vol. 18, p. 497–530, pl. 36–41.

——, & DEADERICK, W. H., 1942, Cretaceous foraminifera from the Brownstown marl of Arkansas: Cush. Lab. Foram. Res., Contr., vol. 18, pt. 3, p. 50–65, pl. 9–14.

——, & ——, 1944, Cretaceous foraminifera from the Marlbrook marl of Arkansas: Jour. Pal., vol. 18, p. 328–342, pl. 50–53.

——, & HEDBERG, H. D., 1941, Upper Cretaceous foraminifera from Santander del Norte, Columbia, S. A.: Cush. Lab. Foram. Res., Contr., vol. 17, pt. 4, p. 81–100, pl. 21–23.

——, & JARVIS, P. W., 1932, Upper Cretaceous foraminifera from Trinidad: U. S. Nat. Mus., Proc., vol. 80, art. 14, p. 1–60, pl. 1–16.

——, & TODD, RUTH, 1943, Foraminifera of the Corsicana marl: Cush. Lab. Foram. Res., Contr., vol. 19, pt. 3, p. 49–72, pl. 9–12.

FRIZZELL, D. L., 1954, Handbook of Cretaceous foraminifera of Texas: Univ. Tex., Rept. Inves. 22, 232 p., 21 pl.

GANDOLFI, R., 1955, The genus Globotruncana in northeastern Columbia: Bull. Amer. Paleont., vol. 36, no. 155, 109 p., 7 pl.

LOETTERLE, G. J., 1937, The micropaleontology of the Niobrara formation in Kansas, Nebraska, and South Dakota: Neb. Geol. Surv., ser. 2, Bull. 12, p. 1–73, pl. 1–11.

REUSS, A. E., 1845, Die Versteinerungen der böhmischen Kreideformation: Stuttgart, 148 p., 51 pl.

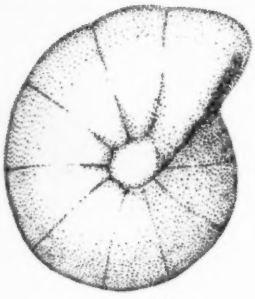
SANDIDGE, J. R., 1932a, Foraminifera from the Ripley formation of western Alabama: Jour. Paleont., vol. 6, p. 265–287, pl. 41–44.

——, 1932b, Additional foraminifera from the Ripley formation in Alabama: Amer. Mid. Nat., vol. 13, p. 333–377, pl. 31–33.

WICKENDEN, R. T. D., 1932, A useful foraminifera horizon in the Alberta shale of southern Alberta: Jour. Paleont., vol. 6, p. 203–207, pl. 29.

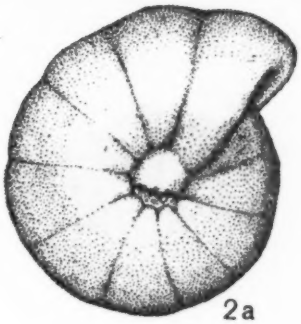
EXPLANATION OF PLATE 97

FIG. *1–5*—*Valvulineria lenticula* (Reuss), ×120. *a*, Ventral view; *b*, peripheral view. Hypotypes Oklahoma University: *1*, KArk 101; *2*, KArk 102; *3*, KBon 101; *4*, KBon 102; and *5*, KArk 103.



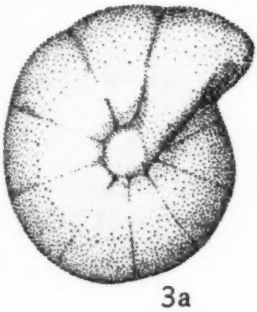
1a

1b



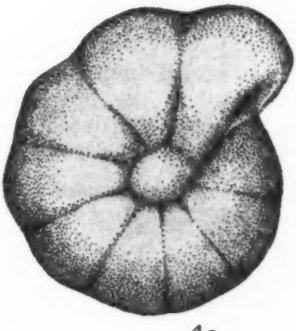
2a

2b



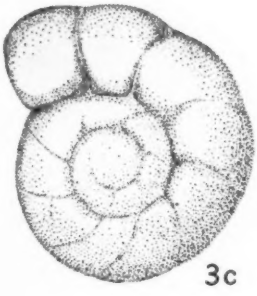
3a

3b

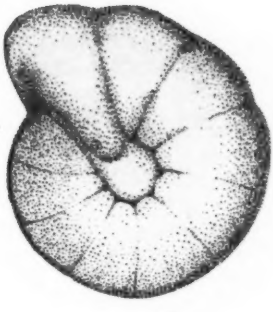


4a

4b



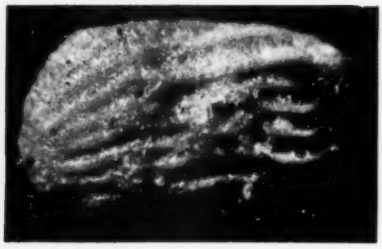
3c



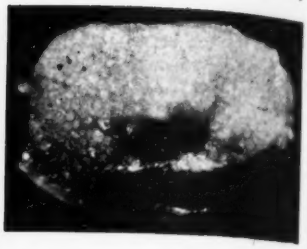
5a

5b

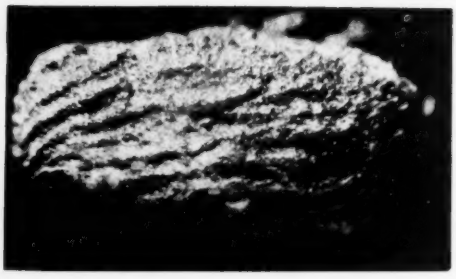
1



2

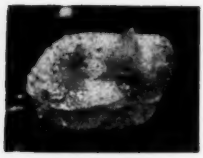


3

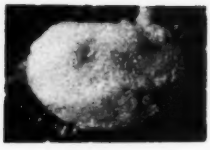


4

5

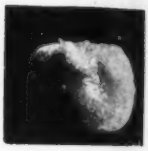


6

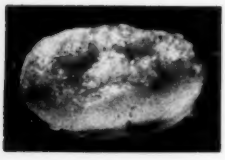


7

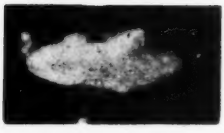
9



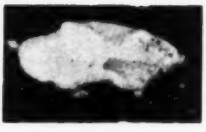
11



12

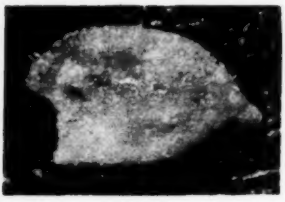


8

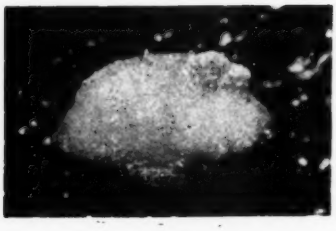


10

13



14



15

16

JOURNAL OF PALEONTOLOGY, VOL. 30, NO. 4, P. 869–875, PL. 98, JULY 1956

A NEW OCCURRENCE OF MISSISSIPPIAN OSTRACODA IN MICHIGAN

MARILYN JOYCE CRANE AND WILLIAM A. KELLY
Michigan State University, East Lansing

ABSTRACT—A newly discovered faunal assemblage of ostracodes and some endothyroid foraminifers contribute to the age determination of the Mississippian Bayport limestone. In this study, fourteen species of ostracodes are described from the Bayport in Arenac County, Michigan. These are represented by four genera: *Glyptopleura*, *Perprimitia*, *Amphissites*, and *Bairdia*. The assemblage shows a similarity to both Chester and Salem faunas.

INTRODUCTION

THE recent discovery of a microfauna in Michigan has added to the criteria for distinguishing the Bayport limestone, the youngest Mississippian formation outcropping in Michigan.

According to Pringle (1937, p. 10), the Bayport is composed principally of alternating beds of white, gray, and buff limestone, with subordinate dolomite and local members of calcareous sandstone. The limestone is dense, semi-lithographic, and contains drusy cavities and a few geodes. Zones of gray to black nodular and lenticular chert are common.

ACKNOWLEDGMENTS

The authors are indebted to Mr. Donald Campau for the collection which he turned over to them. Thanks are also due to Mrs. Jane E. Smith for her interest and many helpful suggestions relating to the nomenclature of ostracodes.

LOCALITY

The type locality is in the vicinity of Bayport, Huron County, Michigan. Other exposures are found in Arenac, Tuscola, Jackson, Eaton, and Kent counties. On the basis of similar megafossils and lithology, the Bayport is thought by G. M. Ehlers & W. E. Humphrey (1944), and others to be the stratigraphic equivalent of the St. Louis limestone of Illinois and Indiana. Megafossils characteristic of the Bayport limestone are tabulated below:

Anthozoa:
- *Lithostrotion proliferum* Hall
- *Lithostrotionella castelnaui* Hayasaka
- *Syringopora ramulosa* Goldfuss
- *Triplophyllites centralis* (Milne-Edwards & Haime)
- "*Zaphrentis*" s. l.

Bryozoa:
- *Dichotrypa* sp.
- *Fenestralia sanctiludovici* (Prout)
- *Fenestrellina exigua* (Ulrich)
- *Polypora tuberculata* Prout

EXPLANATION OF PLATE 98

FIG. *1*—*Glyptopleura cuneata* n. sp., left valve (42×).
2—*Glyptopleura campaui* n. sp., left valve (40×).
3—*Amphissites* sp. 1, right valve (42×).
4—*Glyptopleura* sp. 1, left valve (42×).
5—*Glyptopleura omerensis* n. sp., left valve (44×)
6—*Perprimitia rhomboidea* n. sp., left valve (42×).
7,8—*Perprimitia* sp. 3; *7*, left valve; *8*, dorsal view (42×).
9,10—*Perprimitia* sp. 4; *9*, right valve; *10*, dorsal view (42×).
11—*Perprimitia arenacensis* n. sp., right valve (33×).
12—*Perprimitia* sp. 2; left valve (44×).
13—*Perprimitia* sp. 1; right valve (42×).
14,15—*Bairdia compacta* Geis, *14*, left valve; *15*, right valve (42×).
16—*Bairdia* sp. 1; right valve (42×).

Rhombopora gracilis Ulrich
Sulcoretopora sp.
Taeniodictya ramulosa Ulrich
Taeniodictya subrecta Ulrich

Brachiopoda:

Composita laevis Weller
Echinoconchus alternatus (Norwood & Pratten)
Echinoconchus biseriatus (Hall)
Echinoconchus genevivensis Weller
Linoproductus tenuicostus (Hall)
Productus sp.
Rhipidomella sp.
Spirifer sp.
Spiriferina solidirostris White
Spiriferina subtexta White

Pelecypoda:

Allorisma quadrata Strong
Allorisma strongi Ehlers & Humphrey
Aviculopecten lyelli Dawson
Crenipecten sp.
Sanguinolites sp.

Gastropoda:

Naticopsis sp.
Straparolus sp.
Strobeus sp.

Trilobita:

Griffithides sp.

The microfossils herein described were collected by Donald Campau from a quarry in the S.E. corner of section 34, T. 20 N., R. 5 E., just north of the village of Omer in Arenac County, Michigan. The rocks of this quarry occur near the base of the Bayport formation.

The following, from top to bottom, is a general description of the exposed section (personal communication, D. E. Campau, March 1954).

Bed No.	Description	Thickness
1	gray limestone	13 inches
2	gray limestone (*Allorisma* zone)	6 inches
3	gray limestone	18 inches
4	shaly limestone	6 inches
5	dark gray limestone	6 feet

All the microfossils were collected from the six-inch shaly limestone member, bed 4. Many of the specimens are poorly preserved, being crushed or consisting of internal molds and fragments.

Characteristic of the microfauna is an abundance of foraminifers, provisionally identified as the genera *Paramillerella*, *Orobias* and *Plectogyra*, and currently being studied by Donald Campau. Also abundant are smooth formed Ostracoda of the superfamily Cypridacea. Other sparsely represented ostracodes are included in the superfamily Beyrichiacea. Ostracode genera present include: *Amphissites*, *Bairdia*, *Bythocypris*, *Glyptopleura*, *Kirkbya*, *Perprimilia*, and possibly *Cavellina*, *Healdia*, and *Hollinella*. The latter forms are doubtfully identified because of poor preservation.

This paper is concerned with *Glyptopleura*, *Perprimitia*, *Amphissites*, and *Bairdia*. There are a few good specimens both of *Bythocypris* and *Kirbya*, but no two specimens are alike. For this reason these two genera are not included in the descriptions as there is insufficient evidence to determine whether there are several species present or just one or two species exhibiting several different growth stages.

The orientation of specimens is based upon the suggestions of Levinson (1950) and Kesling (1951). The following is a list of the criteria used for determining orientation:

1.	Muscle scars	anterior
2.	Direction major sulcus slants downward	anterior
3.	Greatest height	anterior
4.	Greatest sulcus	anterior
5.	More obtuse cardinal angle	anterior
6.	Direction of swing	anterior
7.	Widest part of carapace	posterior
8.	Direction of spines and alate extensions	posterior
9.	Pointed end of carapace	posterior
10.	Highest development of hingement	anterior

SYSTEMATIC DESCRIPTIONS

Superfamily BEYRICHIACEA Ulrich & Bassler, 1923

Family GLYPTOPLEURIDAE Girty, 1910

Genus GLYPTOPLEURA Girty, 1910

GLYPTOPLEURA OMERENSIS C. & K., n. sp.

Pl. 98, fig. 5

Carapace oblong, subpolygonal in lateral view; dorsal border straight; ventral border slightly convex; anterior border well rounded ventrally, straight dorsally; posterior border almost straight, not well preserved. In dorsal view left valve is elongate to subcuneate. Greatest width of carapace slightly anteroventral to the center of the posterior half; greatest height a fourth of carapace length from anterior border. Anterior cardinal

angle more obtuse, 155°; posterior cardinal angle 105°.

A pit lies anterior to and slightly above center. A second pit occurs above and slightly anterior to the first. Twelve ribs cross the carapace obliquely, slanting anteroventrally. A prominent rib (Pl. 98, fig. 1), which will be called the primary rib, passes between the two pits, becoming very prominent and spine-like posteriorly. Three ribs occur above the primary rib, the middle one of these being very short and appearing only on the anterior portion of the carapace. Below the primary rib a short rib occurs anterior to the lower pit and unites with the primary rib just above that pit. Another short rib occurs posterior to the lower pit and unites posteriorly to a longer rib that is located below that pit. Five more ribs occur below and parallel to the latter rib. All ribs coalesce anteriorly except: the short rib anterior to the lower pit, the short rib posterior to the lower pit, and the two longer ribs located just below that pit. Hinge line long and straight; nature of hinge contact uncertain. Length, 1.179 mm.; height, .727 mm.; width, .50 mm.

Remarks.—This species which is based on a single left valve is closely related to *G. perbella* (Geis) and *G. genevievea* (Bayer). *G. perbella* is much more rhomboidal in shape. *G. genevievea* has one more rib on the ventral portion of its carapace. Also the lower ribs of *G. genevievea* are not as straight posteriorly. Neither *G. perbella* nor *G. genevievea* has the rib passing between the two pits becoming prominent or spine like posteriorly.

Holotype.—Michigan State University.

GLYPTOPLEURA CAMPAUI C. & K., n. sp.
Pl. 98, fig. 2

Carapace subrhomboidal in lateral view; dorsal border straight; ventral border slightly convex; anterior border much more rounded than posterior border. In dorsal view subcuneate; posterior end blunt, anterior sharp. Greatest width of carapace central posterior; greatest height one-fourth of carapace length from anterior border. Right valve larger, overlapping the left ventrally and posteriorly. Anterior cardinal angle 130°.

A pit lies anterior to and slightly above center. A second pit occurs above and slightly anterior to the first. Twelve ribs cross the carapace obliquely, slanting anteroventrally. A prominent rib, which will be called the primary rib, passes between the two pits, becoming very prominent and spine-like posteriorly. Three ribs occur above the primary rib, the middle one of these being very short and appearing only on the anterior portion of the carapace. Below the primary rib a very short rib occurs posterior to the lower pit. Another short rib is anterior to the lower pit and unites with the primary rib just above that pit. Six more ribs occur below the lower pit, hooking upward posteriorly. Hinge line long and straight. Length, 1.15 mm.; height, .758 mm.; width, .48 mm.

Remarks.—This species is based on three specimens. It is very similar to *G. omerensis*, n. sp. It differs in that it is conspicuously rhomboidal in shape, the lower ribs are more curved posteriorly, and the rib below the lower muscle pit is not connected to the short rib posterior to that pit. *G. perbella* (Geis) is similar to *G. campaui* n. sp. in general shape and arrangement of ribs. The primary rib of *G. perbella* does not become prominent or spine-like. Also its lower ribs are not as curved posteriorly.

Types.—Michigan State University.

GLYPTOPLEURA CUNEATA C. & K., n. sp.
Pl. 98, fig. 1

In lateral view, carapace subrectangular; dorsal border straight; ventral border slightly convex; anterior and posterior borders gently rounded and nearly the same height. In dorsal view, carapace elongate, sides flattened, ends blunt. Greatest width posteroventral. Valves unequal, the right overlapping the left ventrally and anteriorly. Anterior cardinal angle more obtuse, 148°; posterior cardinal angle 125°.

A pit occurs anterior to and slightly above center. Two short ribs occur, one anterior, and one posterior to the pit. The small anterior rib unites just above the pit with a larger rib. This larger rib crosses the carapace obliquely and has a large blunt spine on its posterior end. Above this rib occurs a slightly shorter rib with a small blunt spine or protrusion at the anterior. A short and inconspicuous rib is intercalated between the

latter spinose rib and a faint rib closely paralleling the hinge line. Five ribs occur ventrad to the pit, diminishing in size toward the ventral margin and bending upward posteriorly. The specific name refers to the large wedge-shaped, flattened, posterior spine. Hinge line straight and almost as long as carapace. Length, 1.00 mm.; height, .652 mm.; width, .319 mm.

Holotype.—Michigan State University.

GLYPTOPLEURA sp. 1
Pl. 98, fig. 4

Carapace in lateral view elongate, subovate; dorsal border straight; ventral border slightly convex; anterior and posterior borders gently rounded. In dorsal view highly inflated, elongate, sides gently convex. Greatest thickness posterior; greatest height median. Valves unequal, the right overlapping the left posteriorly and ventrally.

A pit occurs anterior to and slightly above center. A second pit occurs above and anterior to the first. A prominent rib, which is here designated as the primary rib, crosses the carapace obliquely and passes between the two pits. Two small ribs unite with the primary rib just above the lower and most prominent pit, one rib extending anterior, and one posterior to the pit. Below these short ribs are five long ribs paralleling the primary rib. Three more ribs occur above the primary rib, each one shorter than the one below. All ribs are connected anteriorly. Hinge line straight, almost as long as carapace. Length, 1.27 mm.; height, .636 mm.; width, .60 mm.

Figured specimen.—Michigan State University.

Family KIRKBYIDAE Ulrich & Bassler, 1906
Genus AMPHISSITES Girty, 1910
AMPHISSITES sp.
Pl. 98, fig. 3

Carapace subrectangular in lateral view; dorsal and posterior borders straight; anterior border broadly rounded; ventral border gently convex. In dorsal view, carapace strongly convex, ends blunt. Greatest height anterior; greatest width median; overlap not observable. Anterior cardinal angle 90°; posterior cardinal angle 100°.

A round central node occurs slightly ventral to center. A pit occurs just ventral to the node. Velate ridge smooth, prominent, parallel to and above free edge; carina not as well developed and parallel to velate ridge. A faint ridge occurs anterodorsal to the central node and joins a ridge that parallels the hinge line. Another faint ridge occurs along the anterior border. Surface reticulations subpolygonal, medium sized, more or less without orderly arrangement. Hinge line straight and impressed. Length, .95 mm.; height, .62 mm.; width, .55 mm.

Figured specimen.—Michigan State University.

Family KLOEDENELLIDAE Ulrich & Bassler, 1923
Genus PERPRIMITIA Croneis & Gale, 1938
PERPRIMITIA RHOMBOIDEA C. & K. n. sp.
Pl. 98, fig. 6

Carapace with anterior swing, small, subrhomboidal in lateral view; dorsal and posterior borders straight; ventral border gently convex; anterior border rounded. Greatest height anterior; greatest width posterodorsal. Valves unequal, the right overlapping the left ventrally. Anterior cardinal angle 135°; posterior cardinal angle rounded.

A median sulcus is situated slightly anterior to the middle of the carapace. A small node occurs near the dorsal border just anterior to the sulcus. A prominent lobe parallels the ventral border and is separated from the anterior node by a depression. The ventral lobe encroaches on a very prominent posterior lobe or swelling along the posterior border. A narrow furrow separates these two lobes from each other. A well developed spine is situated near the dorsal border between the sulcus and posterior lobe. The hinge line is straight. Length, .515 mm.; height, .379 mm.; width, .26 mm.

Remarks.—This species differs from other known *Perprimitia* in having a straight posterior border. A second specimen, which is crushed, is slightly more elongate and not as rhomboidal.

Holotype.—Michigan State University.

PERPRIMITIA ARENACENSIS C. & K., n. sp.
Pl. 98, fig. 11

Carapace small, subrhomboidal, and with

anterior swing in lateral view; dorsal border straight; ventral and anterior borders gently rounded; posterior border straight ventrally, rounded dorsally. Greatest height of carapace anterior, greatest width posteroventral. Valves unequal, the right overlapping the left ventrally and anteriorly. Anterior cardinal angle 140°; posterior cardinal angle rounded.

A median sulcus lies slightly anterior to the middle of the carapace. The surface is marked by three lobes; an anterior lobe in the anterocentral portion of the carapace, a ventral lobe situated ventrad to the sulcus and parallel to the ventral border, and a spine-like posterior lobe situated in the posterodorsal portion of the carapace. Hinge line straight and slightly depressed. Length, .576 mm.; height, .364 mm.; width, .24 mm.

Holotype.—Michigan State University.

PERPRIMITIA sp. 1
Pl. 98, fig. 13

Valve small, subovate in lateral view; dorsal border straight; anterior and posterior borders broadly rounded; ventral border gently convex. Greatest height just posterior to the sulcus; greatest width posterior. Cardinal angles rounded.

A prominent median sulcus is situated slightly anterior to the middle of the carapace. A node occurs at about mid-height just anterior to the sulcus. A prominent lobe parallels the ventral border. This ventral lobe is separated from the anterior node by a depression. A narrow furrow separates the ventral lobe from a prominent posterior lobe or swelling that follows the posterior border. A small spine is situated near the dorsal border between the posterior lobe and median sulcus. Hinge line straight. Length, .55 mm.; height, .36 mm.; width, 136 mm.

Remarks.—This species differs from *P. funkhouseri* (Croneis & Thurman) in the rounded cardinal angles and position of the spine, which is located beside the posterior swelling and further down from the dorsal border. *P. fraileyi* (Coryell & Rozanski) is different also in the position of the spine and in having a concave dorsal border.

Figured sprecimen.—Michigan State University.

PERPRIMITIA sp. 2
Pl. 98, fig. 12

Carapace small, elongate, and inflated; dorsal border straight; ventral border almost straight; posterior and anterior borders sharply rounded. Greatest height anterior; greatest width posterior. Values unequal, the right overlapping the left ventrally. Cardinal angles rounded.

A prominent median sulcus is situated slightly anterior to the middle of the carapace. A node occurs near the dorsal border just anterior to the sulcus. Ventrad to the sulcus a ventral lobe parallels the ventral border. This lobe is separated from the anterior node by a depression and from a posterior lobe or swelling by a narrow furrow. A small node, instead of a spine, is situated near the dorsal border between the median sulcus and posterior lobe. The hinge line is straight. Length, .55 mm.; height, .34 mm.; width, .30 mm.

Figured specimen.—Michigan State University.

PERPRIMITIA sp. 3
Pl. 98, fig. 7,8

Carapace small, subovate in lateral view; dorsal border straight; ventral border slightly convex; anterior and posterior borders rounded. Greatest height median; greatest width posteroventral. Valves unequal, the right overlapping the left ventrally. Anterior cardinal angle 140°; posterior cardinal angle rounded.

A median sulcus lies slightly anterior to the middle of the carapace. The surface is marked by three lobes; an anterior node in the anterodorsal portion of the carapace, a ventral lobe situated ventrad to the sulcus and parallel to the ventral border, and a spine-like posterior lobe situated in the posterodorsal portion of the carapace. Hinge line straight and depressed. Length, .52 mm.; height, .34 mm.; width, .24 mm.

Remarks.—This species differs from *P. turrita* (Croneis & Gutke) in less overlap, in the rounded posterior cardinal angle, and in having the maximum height median. *P. elongata* (Cooper) is much more elongate.

Figured specimen.—Michigan State University.

PERPRIMITIA sp. 4
Pl. 98, fig. 9,10

Carapace small, elongate, subovate in lateral view; dorsal border straight; anterior and posterior borders rounded; ventral border gently convex and subparallel to dorsal border. Greatest height anterior; greatest width posterior. Valves unequal, the right overlapping the left ventrally. Cardinal angles rounded.

A median sulcus lies slightly anterior to the middle of the carapace. The surface is marked by three lobes; a weak anterior node in the anterodorsal portion of the carapace, a ventral lobe situated ventrad to the sulcus and parallel to the ventral border, and a spine-like posterior lobe situated in the posterodorsal portion of the carapace. Hinge line straight. Length, .55 mm.; height, .32 mm., width, .25 mm.

Remarks.—Similar to *P. elongata* (Cooper), but lacks anterior cardinal angle and is not as elongate.

Figured specimen.—Michigan State University.

Superfamily CYPRIDACEA Dana, 1852
Family BAIRDIIDAE Sars, 1887
Genus BAIRDIA McCoy, 1844
BAIRDIA COMPACTA Geis
Pl. 98, fig. 14,15

Carapace short, medium sized in lateral view; dorsal border broadly arched; posterior slope steep, slightly concave; anterior slope shorter, convex; ventral border straight; posterior end produced into short, sharp, subventral beak; anterior end low (differing from Geis's specimen) and sharply rounded. Ends attenuated in dorsal view, posterior sharply and anterior more greatly compressed. Carapace highest one-third of length from anterior, thickest just posterior to center. Left valve larger with very slight dorsal overlap; hinge simple, short, straight, slightly impressed, and inclined posteriorly; surface smooth. Length, .77 mm; height, .45 mm.; width, .33 mm.

Remarks.—This species is similar to *B.* sp. *9* (Cordell). *B.* sp. *9* differs in having a straight ventral margin and a ventral overlap.

Figured specimen.—Michigan State University.

BAIRDIA sp. 1
Pl. 98, fig. 16

Carapace large, elongate in lateral view; dorsal border convex; anterodorsal slope gently inclined, slightly convex, long; posterodorsal slope straight, somewhat shorter and steeper than anterior slope; ventral border straight; anterior portion of specimen broken; posterior with slight change in curvature, no definite beak. In dorsal view, ends attenuated, the anterior gradually, the posterior more sharply compressed. Greatest length ventral; greatest height posterocentral; greatest width posterocentral. Length, 1.49 mm.; height, .64 mm.; width, .44 mm.

Figured specimen.—Michigan State University.

SUMMARY

Two species of *Glyptopleura* in this study, *G. campaui*, n. sp., and *G. omerensis*, n. sp., are very closely related respectively to *G. perbella* (Geis) and *G. genevievea* (Bayer) of the Salem. This association, along with the occurrence of *Bairdia compacta* (Geis) in the Bayport limestone, leads to speculation that in Michigan the Salem may be present as a thin member of the basal Bayport. However, the evidence is very scant and not conclusive due to the habit of some forms to persist through long intervals of time and thus be of little value as guide fossils. *Glyptopleura campaui*, *G. omerensis*, and *Bairdia compacta* (Geis) may represent a recurrence of an environmental condition similar to that which characterized the Salem. Supporting the latter contention is the presence of the foraminiferal genera, *Paramillerella*, *Orobias*, *Plectogyra* and the ostracod genus *Perprimitia*. Before this study was made these forms had been found only in rocks of Chester age. This occurrence may suggest that the Bayport is younger than the Salem. However if the Bayport is the time equivalent of the St. Louis, as has been determined by the study of megafossils, it would mark the oldest occurrence of these two genera. Further work on the Mississippian sequence of Michigan may, however, indicate that the apparent anomalous sequence is the result of environmental factors.

BIBLIOGRAPHY

CORDELL, R. J., 1952, Ostracodes from the Upper Pennsylvanian of Missouri; Part I, The family Bairdiidae: Jour. Paleont., vol. 26, p. 74–112, pl. 17–20.

CORYELL, H. N., & BRACKMIER, GLADYS, 1931, The ostracode genus *Glyptopleura:* Am. Midland Naturalist, vol. 12, p. 505–521, pl. 1,2.

CRONEIS, CAREY & GUTKE, R. L., 1939, New ostracodes from the Renault formation: Denison Univ. Bull., Jour. Sci. Labs., vol. 34, p. 33–63, pl. 1,2.

EHLERS, G. M., & HUMPHREY, W. E., 1944, Revision of E. A. Strong's species from the Mississippian Point Au Gres limestone of Grand Rapids, Michigan: Mich. Univ. Mus. Paleont., Contr., vol. 6, p. 113–130, pl. 1–3.

GEIS, H. L., 1932, Some ostracodes from the Salem limestone, Mississippian, of Indiana: Jour. Paleont., vol. 6, p. 149–188, pl. 22–26.

KESLING, R. V., 1951, Terminology of ostracod carapaces: Mich. Univ. Mus. Paleont., Contr., vol. 9, p. 93–171, pl. 1–18.

LEVINSON, S. A., 1950, The hingement of Paleozoic Ostracoda and its bearing on orientation: Jour. Paleont., vol. 24, p. 63–75.

PRINGLE, G. H., 1937, Geology of Arenac County: Mich. Dept. Conserv., Geol. Surv. Div., Prog. Rept. 3, p. 1–31, pl. 1–6.

JOURNAL OF PALEONTOLOGY, VOL. 30, NO. 4, P. 876–882, PL. 99, 100, 1 TEXT-FIG., JULY 1956

KHMERIA AND *TRACHYPSAMMIA* FROM THE PERMIAN OF SOSIO, SICILY

EUGENIA MONTANARO GALLITELLI
University of Modena, Italy

ABSTRACT—Recent studies of the Permian coral fauna from the Sosio Valley have provided new data on the morphology and taxonomy of two peculiar coral genera. Investigation of the Sosio material demonstrated that the operculate genus *Khmeria* Mansuy [=*Osium* De Gregorio] is a rugose coral, not some other organism; but its systematic relationships within the order Rugosa are still uncertain. A new interpretation of the structure of *Trachypsammia* Gerth definitely establishes the systematic position of this genus in the subclass Alcyonaria. The order Trachypsammacea has been erected for alcyonarian corals characterized by the particular combination of structural features typically developed in *Trachypsammia*.

INTRODUCTION

IN THE Palaeontographica Italica (1954) the writer described and illustrated in detail the coral fauna of the Sosio basin. Two unusual genera that are inadequately described in the earlier literature occur in this fauna. As it is entirely possible that these genera may also occur in the Permian rocks of the Western Hemisphere, the writer was urged to describe the peculiar morphologic features of both genera and to summarize in English her ideas about their structure and relationships.

Some problems pertaining to the systematic position of *Khmeria* Mansuy and *Trachypsammia* Gerth are still unsolved. The present paper is intended to invite discussion about the taxonomic status and evolutionary significance of these remarkable corals.

ACKNOWLEDGMENTS

The writer acknowledges the help of Dr. H. Gerth (University of Bonn, Germany), G. Kruinzinga (Tecknische Oogeschool, Delft, Holland), and A. Schouppé (University of Graz, Austria), who lent or presented specimens for study and comparison. Dr. G. A. Cooper of the United States National Museum, Washington, kindly examined the specimens of *Khmeria* and concurred with the writer's opinion that these fossils were not Brachiopoda. The writer is much indebted to Miss Helen Duncan of the U. S. Geological Survey and to Dr. Frederick M. Bayer of the U. S. National Museum, who kindly read the manuscript and gave many profitable systematic suggestions and new documentation about *Khmeria* and *Trachypsammia* respectively.

This paper was written in 1955 during the sojourn of the writer in Washington, D.C., as a visiting paleontologist at the U. S. National Museum. Financial assistance was provided by a grant from the Italian National Research Council and a Fulbright travel grant. The writer extends her thanks to all authorities concerned.

SYSTEMATIC DESCRIPTIONS

Order RUGOSA
Family KHMERIDAE Montanaro Gallitelli, 1954

Type of the family: *Khmeria* Mansuy, 1914.

Diagnosis.—Corallum simple or more rarely compound. Corallites turbinate or scolecoid. Operculum simple or compound, crenulated at the margin, without hinge. Septa degenerated or absent. Tabulae and vesicles well developed. Pennsylvanian-Permian.

Discussion.—Mansuy (1914) originally discovered this fossil in the Upper Permian of Cambodia, Indochina, and published a description and many illustrations of the type species, *Khmeria problematica* Mansuy. Unfortunately Mansuy did not figure any sections illustrating the internal structure. Later, Yabe & Ma (1932) described the same species from the Permian of Nagato (horizon with *Sumatrina annae*) and figured

a rather poor thin section of a specimen having traces of a few tabulae.

A Sosio species, now referred to *Khmeria*, was originally described as *Osium importans* by De Gregorio (1930), who did not give an adequate description or discussion of the peculiar specimens. As a result of recent morphologic studies by the writer, (1) the generic identity of *Osium* and *Khmeria* was established; and (2) the well preserved and unusual internal structure, which was investigated by polished and thin transverse, tangential, and longitudinal sections, was illustrated. The writer's investigation of the internal structure and the external characters of the skeleton furnishes new data for interpreting the genus, for affirming its anthozoan nature, and for recognizing probable relationships of *Khmeria* with the cystiphylloid corals that make their final appearance in the Permian of Timor.

Khmeria exhibits aberrant features that have caused the fossil to be considered a "problematicum." For this reason comparison with other classes of Invertebrata is required.

The absence in *Khmeria* of a pseudodeltidium indicates that the genus cannot possibly be related to such Brachiopoda as *Richthofenia*, and the absence of a subcardinal myophore apophysis precludes establishing affinities with *Gemmellaroia*, another coral-like brachiopod.

Khmeria was compared also with certain vesiculate Calcispongiae (*Amblysiphonella vesiculosa* De Koninck and *A. radicifera* Waagen & Wentzel) having a large central canal (the cloaca) and parietal vesicles. But in *Amblysiphonella* the vesicles are restricted to the peripheral chambered zone, and the wall of the central canal is always perforated by large openings (0.5 to 1.5 mm. in diameter), a feature that is quite different from the continuous wall observed in *Khmeria*.

The absence of muscle scars, pallial scar, hinge, or teeth excludes any relationship with the Pelecypoda.

Elimination of the possibility that *Khmeria* was allied to sponges, brachiopods, or pelecypods strengthens the case for interpreting the organism as a coral. It differs from the majority of Paleozoic Rugosa in lacking true septa. However, marginal undulations that suggest septal ridges occur on the internal side of the operculum. Investigation of young specimens and of the neanic stage of large specimens demonstrates that the absence of septa is not a secondary feature.

Other operculate corals (*Calceola*, *Goniophyllum*, *Rhizophyllum*), on the contrary, have rudimentary but definite septal apparatus. Other corals with greatly reduced septa are known. In these forms tabulae and vesicles fill the lumen of the corallites. The most extreme development in this trend occurs in genera of the Cystiphyllidae in which cystose deposits increase at the expense of the septa, and the latter are sometimes reduced to such an extent they are hardly recognizable.

Reduction of septa had progressed even further in the Permian species described by Koker as *Cystiphyllum diplochone* and *Cystiphyllum ultimum* (Pl. 99, fig. 14). The Cystiphyllidae, however, did not persist beyond Middle Devonian time, and the two species identified by Koker (1924) as "*Cystiphyllum*" can hardly be interpreted as true *Cystiphyllum* because of the different habitus and development of the vesicular system and of the tabularium.

In the last days of the writer's stay in the U. S. National Museum, Helen Duncan suggested that *Khmeria* might be compared with the Lower Carboniferous genus *Cystelasma* Miller. This genus is known from the Mississippian Salem limestone and other rocks of Meramecian age (Viséan) in the Mississippi Valley region. So far *Cystelasma* has been recognized only in the United States. Time was not available for making necessary transverse and longitudinal sections. However, the morphologic characters of *Cystelasma* offer many elements for comparison with both "*Cystiphyllum*" Koker and of *Khmeria* Mansuy. In individuals of some species of *Cystelasma* (Pl. 99, fig. 15a,15b) septa are almost completely lacking; vertical undulations and vague ridges are visible only near the the upper margin of the corallite. The tabularium is composed of irregularly disposed transverse elements; large inflated vesicles are developed. The structure of the wall could not be adequately investigated by sections because the specimens are recrys-

tallized; however, broken specimens show a rather thick wall, which seems not to be compact but somewhat reticulate or alveolar. A careful study of this Mississippian coral genus is needed in order to establish its systematic position and its possible relationships not only with *Khmeria* but also with the two Permian cystiphylloid corals identified by Koker as *Cystiphyllum*.

Genus KHMERIA Mansuy, 1914 (emend. Montanaro Gallitelli, 1954)

Genotype: *Khmeria problematica* Mansuy, 1914.

Generic diagnosis.—Corallum simple or rarely compound; corallites sometimes aggregated in clusters, generally irregular in shape, turbinate to scolecoid; variable in size, from 10 to 100 mm. in length. Surface rugose, imperforate, with irregular transverse ridges or bourrelets. Operculum independent; simple or compound. Tabularium generally well developed. Vesicles well developed, irregular, inflated, extending in places from the margin nearly to the axial region, developed mainly between the tabulae. Septa essentially absent.

Occurrence.—Type material of *K. problematica:* Upper Permian of Cambodia, Indochina. Other specimens and species: Lower Pennsylvanian Tarma group (probably of Atokan age) of central Peru (Mr. R.M. Finks showed to the writer three fragmentary specimens collected near Pomachaca, 1 km. southeast of Pomachaca village, approximately 6 km. north of Tarma). Upper Permian (*Sumatrina annae* zone) of Nagato, Japan; Sosio Valley, Sicily, Italy.

Discussion.—The relationships of this fossil were problematic according to Mansuy, because certain internal deposits normally present in Zoantharia were not observed. But specimens from Nagato, Japan, identified as the same species by Yabe & Ma, exhibit internal deposits ("rather straight tabulae, either complete or incomplete, disposed more or less horizontally and sometimes quite obliquely and then coalescing into one another"). It is clear that *K. problematica* from Japan and the species from Cambodia and Sicily belong to the same genus; therefore the writer suspects that only a few poorly preserved specimens were available to Mansuy for sections. The writer hoped to get paratypes or topotypes of *K. problematica* for study, but was informed by M. Roger, of the Centre de Documentation paléontologique of Paris, that all the material studied by Mansuy is deposited in Hanoi, Indochina, and therefore is not available.

KHMERIA IMPORTANS (De Gregorio) Pl. 99, fig. 1–13

Osium importans De Gregorio, 1930, Ann. Géol. Paléont., Palermo, livr. 52, p. 45, pl. 7, fig. 10–17.

Khmeria importans Montanaro Gallitelli, 1954, Paleontographia Ital., vol. 49, p. 55, pl. 3, fig. 1–22, 28–32; pl. 4, fig. 1–6.

Diagnosis.—Corallum simple, rarely composite; operculate; ceratoid, or more often curved-cylindrical to scolecoid. Apical region obtuse, without a demonstrable scar of attachment; depressed area observed at the base of a few specimens. Operculum simple; either hood-shaped or more rarely obtusely conical; radially crenulated on the internal margin, the radial elements crossed by concentric striae. Undulations on the internal surface of the operculum commonly present. Surface of the corallite rough, uneven owing to intermittent constrictions and bourrelets; indications of rejuvenescence observed. Transverse ornamentation is undulatory and irregular. Interseptal costae or ridges absent; only tangential sections in neanic stages show very thin vertical elements 0.05 mm. apart. Distal end of the corallite rarely crenulate. Upper surface of the operculum concentrically striated. Epitheca not clearly visible because of fossilization; apparently a thin external layer superimposed on a vacuolate thick "wall." Septal deposits lacking in both neanic and ephebic stages. Internal cavity crossed by a series of transverse tabulae-like partitions and containing a system of more or less well developed vesicles.

Occurrence.—Holotype and figured hypotypes: Middle Upper Permian, Pietra di Salomone, Sosio Valley, Province of Palermo, Italy.

Depository of the figured hypotypes.—Istituto di Geologia, University, Pisa.

Order TRACHYPSAMMACEA Montanaro Gallitelli, n. order

Coralla dendroid. Medullar canal system and cortical radiate coenenchyme. Corallites arise from the medullar canal.

Discussion.—Structural studies were made by the writer on perfectly preserved specimens of *Trachypsammia* Gerth, which was widely distributed in the Paleotethys during Permian time. Both of the fundamental characters—a central longitudinal canal system and a radial cortical coenenchyme—occur with similar peculiarities of details in different orders of Alcyonaria. However, no representative of the known orders combines these structural characters. Radial arrangement of coenenchymatic spiculae and sclerodermites may occur in Alcyonaria. Structural research and observations in polarized light made by Frederick M. Bayer on the Gorgonacea (*Isis hippuris* Linnaeus and *Suberia clavaria* Studer), during the stay of the writer in the U. S. National Museum, demonstrate unquestionable structural similarities with *Trachypsammia*. But neither *Isis* nor other holaxonian Gorgonacea have a longitudinal central canal system as seen in *Trachypsammia*. On the other hand, strikingly similar canal systems are found in certain scleraxonian Gorgonacea, Alcyonacea, and Telestacea, which, however, have a different origin of corallites and furthermore lack the radial arrangement of the coenenchyme. Consequently, inclusion of the family Trachypsammiidae Gerth in the Alcyonaria is indicated, and a new order has been established to accommodate this structurally divergent category.

Family TRACHYPSAMMIIDAE Gerth, 1921

Diagnosis.—Corallum compound, dendroid; corallites originating from a medullar canal system. Cortical coenenchyme well-developed, consisting of a vertical system of radiating laminae intersecting concentric vesicular lamellae; coenenchymatic pores and lumina present. No tabulae.

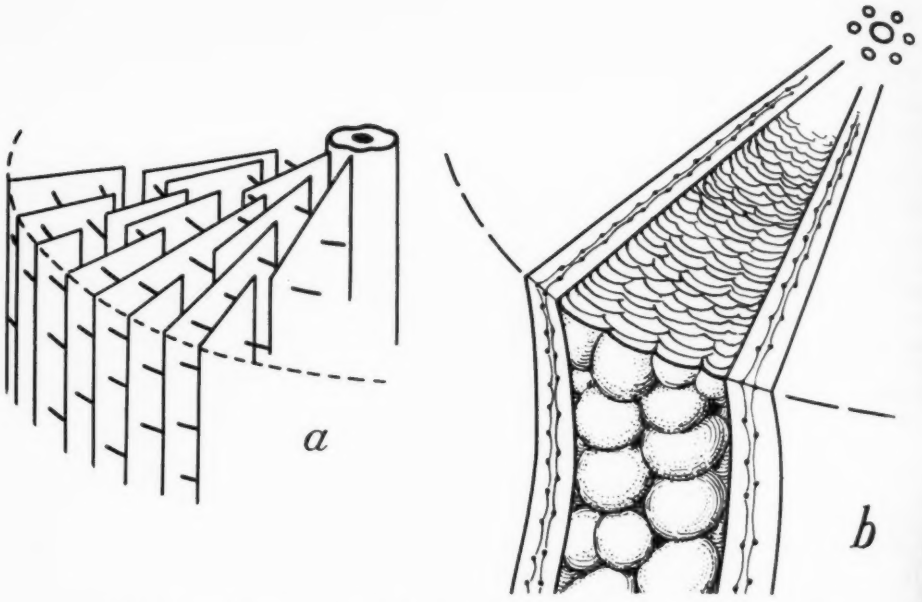
Discussion.—The first description of this unique coral was given by Gerth (1921), who studied specimens from the Upper Permian of Timor. He recognized the peculiarities of the genus and referred it to the Tabulata, near the Pachyporidae, although with some trepidation because of the structure of the extramedullary skeleton and the external sculpture, which he compared with the coenenchyme and sculpture of Tertiary and living Scleractinia of the families Oculinidae, Eupsammiidae, and Dendrophylliidae. Gerth also recognized the possibility that the Trachypsammiidae could be referred to the Octocorallia, which some authors have considered to be closely related to the Tabulata.

The structure and systematic position of this fossil were subsequently discussed by Hehenwarter (1951), who excluded any connection with the Pachyporidae, emphasized the possible relationship with the Octocorallia previously suggested by Gerth, and related *Trachypsammia* with the Gorgonacea, but gave an erroneous interpretation of the structure (Text-fig. 1). Recent investigation by the writer of topotypes of the type species and of a new species, *T. mediterranea* Montanaro Gallitelli, resulted in a revised structural interpretation and an attempt to verify the relationship with the Octocorallia. Affinity with fossil colonial forms like *Pachypora* is definitely and obviously ruled out.

Although the medullar system can in general be compared with that of the Octocorallia, identity of *Trachypsammia* with known forms is not possible because of its combination of a central medullar canal system, extramedullar radial coenenchyme, and production of new corallites from the central medullar canal.

Relationship with the Gorgonacea, as suggested by Hehenwarter, is not possible because of the existence of a strongly developed mesoskeleton and the great difference in structure and development in the medullar region, which in the Gorgonacea is an ectodermal product consisting of succeeding overlapping cupuliform lamellae, or concentric lamellae more or less calcified, or radially oriented irregular sclerodermites in the center surrounded in the older parts by secondary calcification arranged either radially or longitudinally.

With reference to other types of modern Octocorallia, *Trachypsammia* differs from



TEXT-FIG. *1*—The structure of *Trachypsammia* Gerth. *1a*, after Hehenwarter: *1b*, after the writer.

the Stolonifera (e.g., *Tubipora*) that have parallel corallites connected only by horizontal stolonic platforms penetrated by gastrodermal canals. A similarity can be recognized with certain forms of Telestacea and Alcyonacea in which young corallites arise at various levels from the solenial system of the vertical corallite walls of the parent. *Trachypsammia* could be considered as far as the medullar system is concerned, as an archaic precursor of this type of structure, having a single primary basal polyp and a single central medullar structure with one large central cavity (therefore different from such forms as *Briareum*). Some fascinating structural similarities of certain Alcyonaria to the radiating extramedullar coenenchymatic system of *Trachypsammia* have been pointed out to me recently by F. M. Bayer. After discussing with the writer the probable systematic relationships of *Trachypsammia*, Bayer

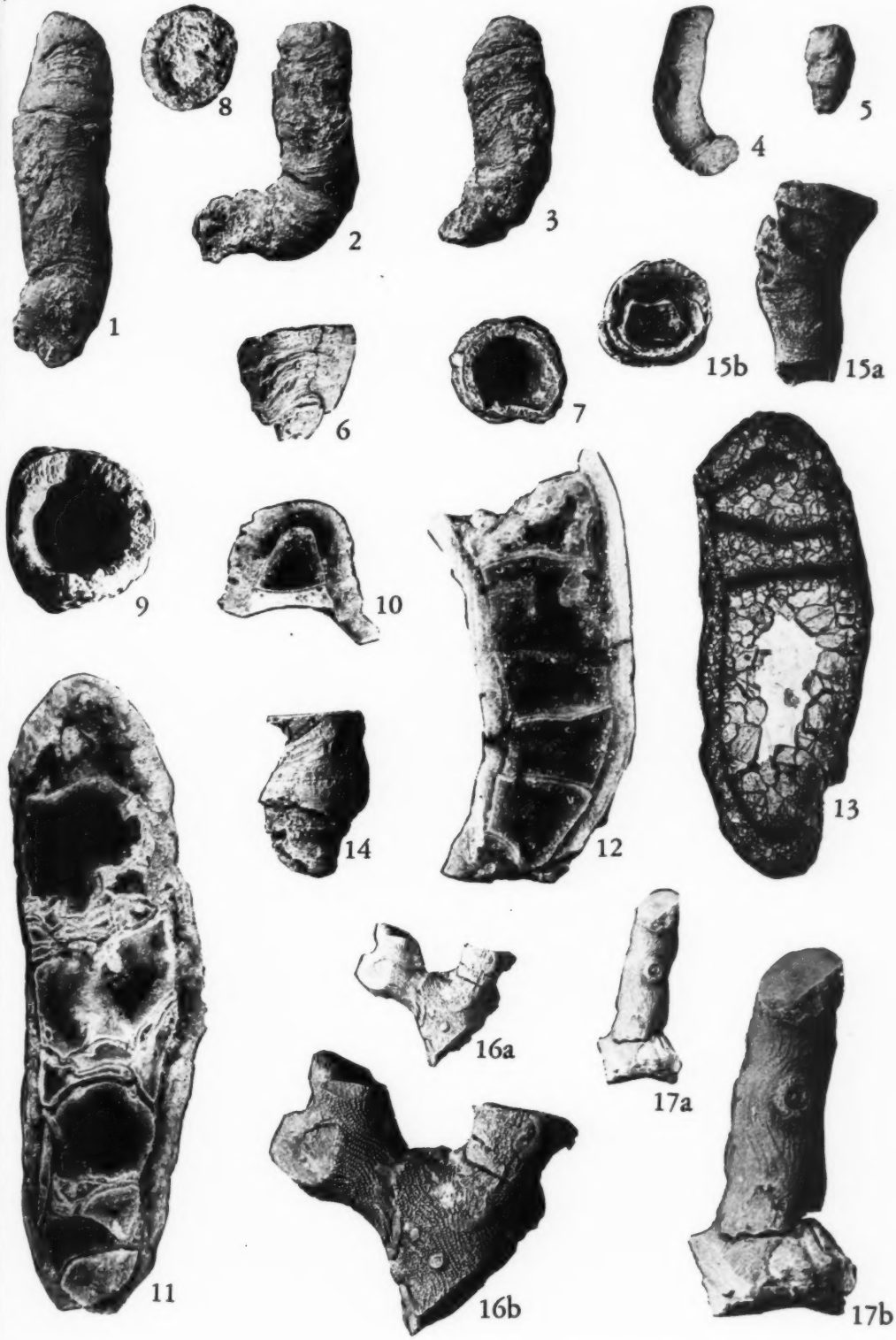
EXPLANATION OF PLATE 99

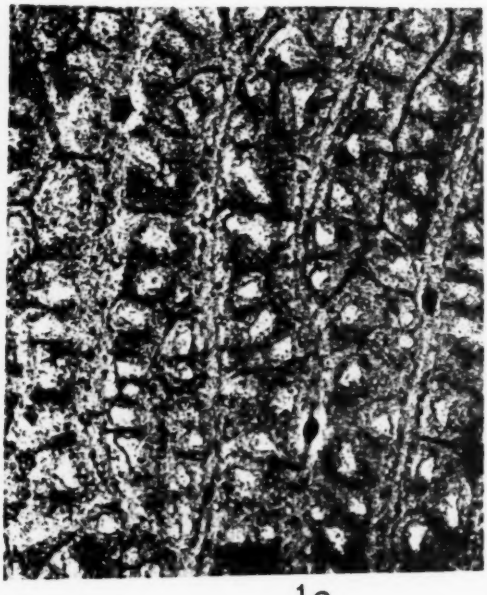
FIG. *1–13*—*Khmeria importans* (De Gregorio). *1–5*, complete specimens with opercula, all ×1. *6–8*, Opercula, ×1. *9*, Operculum, ×2.5. *10*, Operculum in polished section, showing internal structure, ×2. *11–12*, Polished longitudinal sections of two specimens, showing "tabulate" and vesicular internal structure, ×3. *13*, Thin longitudinal section of a young specimen, ×7. Repository of figured specimens: Geol. and Paleont. Institute, University, Pisa, Italy.

14—*Cystiphyllum ultimum* Koker. View of corallum, ×1. Repository: Montanaro Gallitelli collection, Paleont. Institute, University, Modena, Italy.

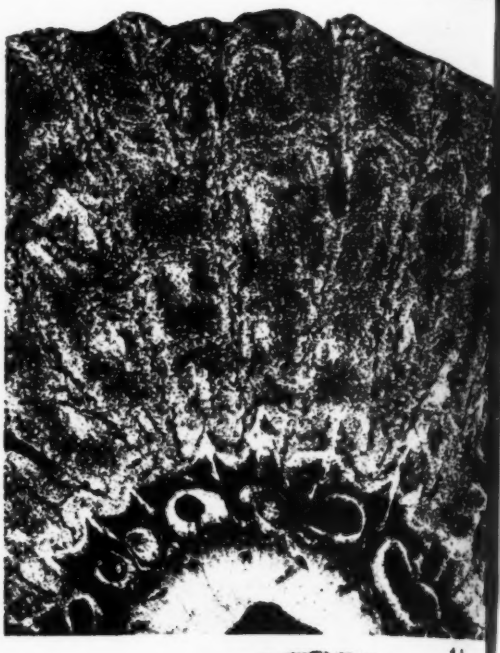
15a–15b—*Cystelasma lanesvillensis* Miller. *15a*, Side view of corallum. *15b*, Calyx, showing cystose tabulae and traces of septal ridges. Both views of USNM 125302a, ×2.5. Repository: U.S. National Museum, Washington, D. C.

16–17—*Trachypsammia mediterranea* Montanaro Gallitelli. *16a*, Fragment of ramifying corallum, showing a corallite and well-developed surface sculpture. ×1; *16b*, same specimen, ×2. *17a*, Fragment of a corallum with a smoother surface, showing basal portion and a corallite, ×1 *17b*, same specimen, ×2. Repository: Montanaro Gallitelli collection, Paleont. Institute University, Modena, Italy.

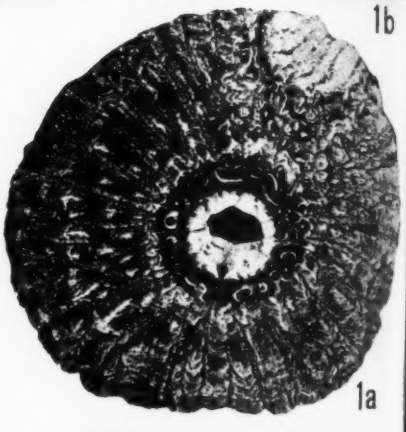

1
8
2
3
4
5
15b
15a
6
7
9
10
12
13
14
11
16a
16b
17a
17b



1c

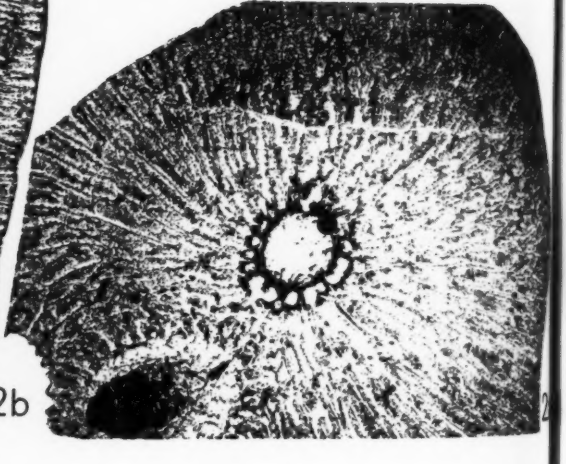


1b



1a

2b



2

studied a series of thin sections of Gorgonacea and Alcyonacea in polarized light and kindly allowed the writer to see the unpublished results of his investigations. The detailed description and discussion of this investigation is left to Dr. Bayer, but it is important to note here that such Gorgonacea as *Isis hippuris* Linnaeus and *Corallium rubrum* Linnaeus show a singularly analogous radial arrangement of the sclerodermites in the calcareous axis. These forms differ from *Trachypsammia* in the absence of the central canal system, but this is present in the gorgonacean genus *Suberia* (with unconsolidated skeleton), which, moreover, has a very open vesicular cortex that may show traces of a radial arrangement.

Genus TRACHYPSAMMIA Gerth, 1921
Pl. 99, fig. 16,17; Pl. 100

Genotype: *Trachypsammia dendroides* Gerth, Paläontologie von Timor, Lief. 9, p. 116, pl. 149, fig. 14–20; pl. 150, fig. 19.

External characters.—Corallum compound, dendroid, adherent by a broadly cuneiform base. Ramification beginning about 2 cm. from the base. External sculpture of minute tubercles in single or double files, separated by thin ridges axially or sinuously directed, increasing in number and sometimes anastomosing, chiefly in the vicinity of the corallites. Calices minute, generally biserial, less often sparsely scattered; slightly projecting, with coronal tubercles and wall subdivided into a variable number of sectors simulating septal striae.

Structure of coenenchyme.—The medullar region is formed of a system of sinuous labyrinthine canals with frequent anastomoses and ramifications (Pl. 100, fig. 1b,2a,2b). Corallites originate in the canalicular region as new axial processes inserted in the canal system, which becomes peripheral to them as growth proceeds. One or more canals penetrate the developing skeleton and form the axial cavity of the new corallite. The corallite bends centrifugally as it elongates, the central cavity becomes funnel-shaped and the calcaerous column becomes subdivided in a series of 24 to 28 radiating sectors (the "septal ridges" of Gerth and Hehenwarter). In the mature stage the peripheral canals are arranged in a series around the calicular margin.

Extramedullar tissue.—Transverse, axial, and tangential thin sections demonstrate the following structures: (1) A system of vertical, concentric thin lamellae (the "interradial bridges" of Hehenwarter; Text-fig. 1a), which are finely and regularly vesicular (Pl. 100, fig. 2a,2b; Text-fig. 1b) and produce the external sculpture of winding files of "tubercles"; (2) a system of longitudinal, septum-like lamellae 28 to 50 in number, crossing the concentric system, undulating mostly in a vertical direction and occasionally anastomosing as shown in tangential sections (Pl. 100, fig. 1c; Text-fig. 1b); (3) a reticulate system of minute dark point (pores?) on each side of the septum-like lamellae visible even at low magnification (×5) in both tangential and cross sections; (4) a system of relatively few and large cortical lumina irregularly dis-

EXPLANATION OF PLATE 100

FIG. *1*—*Trachypsammia mediterranea* Montanaro Gallitelli. Thin sections from specimen figured on plate 99, figure 17. *1a*, Transverse section of branch, showing canaliculate medullar area, radiate vesicular peripheral portion, and (at the left) inception of a corallite, ×9. *1b*, Part of same section, showing details of structure in medullar and radiate portions, ×26. *1c*, Tangential section, showing structure of the "tubercles" and vertical intertuberculate sulci, ×35. Repository: Montanaro Gallitelli collection, Paleont. Institute, University, Modena, Italy.

2—*Trachypsammia dendroides* Gerth. Thin sections of holotype. *2a*, Transverse section, ×8. *2b*, Vertical section through axis, showing radiate peripheral and canaliculate medullar portions and four corallites in different stages of development; the upper corallite appears in the transverse section (fig. *2a*), ×6. Repository: Wanner collection, Paleont. Museum, University of Graz, Austria.

posed on the sides of the vertical radiate lamellae (Pl. 100, fig. 1c).

Dimensions.—Fragmentary colonies 1.5 to 6 cm. in length, 0.5 to 2.0 cm. in diameter.

Occurrence.—The genotype: Upper Permian, Basleo, Timor. *T. mediterranea* Montanaro Gallitelli: Middle Upper Permian, Pietra di Salomone, Sosio Valley, Palermo (Italy).

REFERENCES

De Gregorio, A., 1930, Sul Permiano di Sicilia (Fossili del calcare con Fusulina di Palazzo Adriano non descritti dal prof. G. Gemmellaro conservati nel mio privato gabinetto): Annales Géol. Paléont., Palermo, livr. 52.

Gerth, H., 1921, Die Anthozoën der Dyas von Timor: Paläont. von Timor, Lief. 9, Teil 16, p. 65–147, pl. 145–150.

Hehenwarter, E., 1951, Ergänzungen zur Tabulatenfauna des Perm von Timor und zur Stellung des Genus *Trachypsammia* Gerth: Palaeontographica, Suppl. Bd. 4, Abt. 5, Lief. 2, p. 59–93, pl. 4–6.

Koker, E. M. J., 1924, Anthozoa nit het Perm van het Eiland Timor: Jaarb. mijnwezen Ned.-Indië, Jaarg. 51 (1922) Verhandelingen, p. 1–50, 11 pl.

Mansuy, H., 1914, Faunas des Calcaires à Productus de l'Indochine: Indochine Service géol. Mém., ser. 2, vol. 3, fasc. 3.

Montanaro Gallitelli, E., 1954, Il Permiano del Sosio e i suoi Coralli: Palaeontographica Italica, vol. 49, p. 1–98, pl. 1–10.

Yabe, H., & Ma, T. Y., 1932, *Khmeria problematica* Mansuy from Japan: Japan. Jour. Geol. Geog., vol. 10, p. 61–65, pl. 5.

JOURNAL OF PALEONTOLOGY, VOL. 30, NO. 4, P. 883–890, PL. 101,102, 6 TEXT-FIG., JULY 1956

NEW FORAMINIFERA FROM THE CENOMANIAN OF SINAI, EGYPT

S. OMARA
University of Cairo, Egypt

ABSTRACT—The genus *Thomasinella* Schlumberger, 1893, is emended and two new species described, *T. aegyptia* and *T. fragmentaria*. Ontogenetic variations in this genus suggest that *Reophax* Montfort, 1808, is an ancestral type and that *Thomasinella* may be placed in the family Reophacidae. *Cribrostomoides sinaica*, n. sp., *C. paralens*, n. sp., and *Nezzazata simplex*, n. gen., n. sp., are also introduced. The stratigraphic significance of the foraminifers is discussed.

INTRODUCTION

THE Cenomanian rocks of Nezzazat, an area on the western coast of the Sinai Peninsula, have yielded an interesting association of foraminifers in a good state of preservation. Among the forms observed there are arenaceous branching specimens which are similar to *Thomasinella punica* Schlumberger, 1853. A careful restudy of this genus based on specimens from Nezzazat as well as the original species (collections of H. B. Brady in the British Museum of Natural History) showed fundamental relationships between *Thomasinella* Schlumberger, 1889, and *Reophax* Montfort, 1808.

Genus *Cribrostomoides* Cushman, 1910, emend. Frizzel & Schwartz, 1950, is represented by two new species which are described and illustrated. A rotaliid foraminifer was observed in which its apertural characteristics and the micro-structure of its test necessitated the erection of a new genus with a new species as genotype.

ACKNOWLEDGMENTS

Thanks are due to Professor S. E. Hollingworth and Dr. T. Barnard for the use of facilities of the Geology Department, University College, London; to C. Deilmann Bergbau, Bentheim, Germany, for facilities provided in their micropaleontological laboratory. A special word of gratitude is due to the authorities of the British Museum (Natural History), London, who have given the author the permission to examine and photograph their seven specimens of *Thomasinella punica* and to section one of them. Thanks are also due to Dr. H. Hiltermann for critically reading the manuscript.

Disposition of types.—The holotypes and some paratypes, inclusive of the figured paratypes of only *Thomasinella aegyptia*, are deposited in the American Museum of Natural History, New York. Other paratypes are in the collections of the Amt für Bodenforschung, Hannover, Germany. Thin sections and more paratypes, inclusive of the figured ones, will be deposited in the collections of the Geology Department, University of Cairo.

SYSTEMATIC DESCRIPTIONS

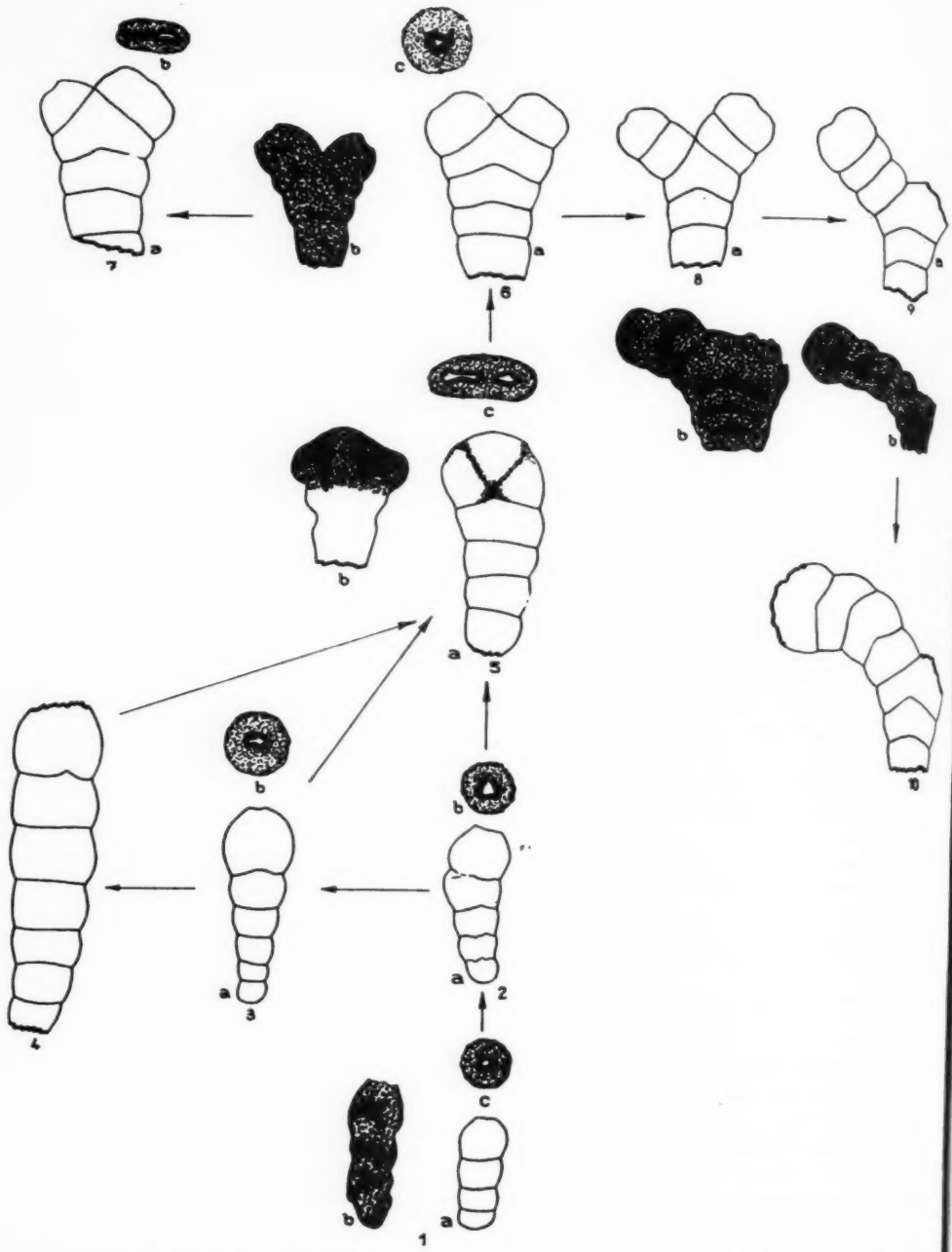
Genus THOMASINELLA Schlumberger, 1893, emend.

Genotype: *Thomasinella punica* Schlumberger, 1893.

Genus *Thomasinella* was first proposed by Schlumberger in 1889, and described by him (1893), with two species *Thomasinella rugosa* and *T. punica* as genotypes. Schlumberger's definition of *Thomasinella* is "Plasmostracum arborescent, composé de loges superposées se bifurquant plus ou moins régulièrement et à plusieurs reprises. Test arénacé épais. Ouvertures aux extrémités de chaque branche."

Thomasinella is emended to include unbranched uniserial, linear or slightly curved arenaceous foraminifera, distinguished by terminal simple apertures.

Diagnosis.—Test large, uniserial or bifurcating; chambers successively increasing in size, either discoidal or nodulose, sometimes slightly inflated with roughly circular cross-section, in other cases compressed and flattened and more or less pentagonal in shape; sutures either straight with occasional fine indentations or chevron-shaped; chamber-cavities simple separated by septal walls or connected; wall arena-



TEXT-FIG. *1*—Ontogenetic relationships observed among different individuals of *Thomasinella aegyptia*, n. sp.
1—Nepionic form, ×13. *1b*, longitudinal section; *1c*, apertural view.
2–4—Neanic forms (*2,3* ×13; *4* ×15). *2b* & *3b*, apertural views.
5—Ephebic form ×13. *5b*, longitudinal section; *5c*, apertural view.
6–10—Gerontic forms (*6–9* ×13; *10* ×15). *6b,8b* & *9b*, longitudinal sections; apertural views *6c* & *7b*.

ceous, thick, simple or labyrinthic mainly formed of quartz grains, in other cases the wall is mainly formed of fossil remains agglutinated in a calcareous whitish or ferruginous brownish cement. Aperture in the young, simple, terminal, either rounded, polygonal, slit-shaped or irregular; in the adult, two elongate slits trend to the flattened side of the last-formed chamber, later mostly rounded or polygonal aperture, or two slit-like apertures at the end of each branch.

Remarks.—The arrangement of chambers in *Thomasinella* differs in the different stages of individual development. On morphologic grounds, the early uniserial types of growth (juvenile forms), from which the branching types are derived, are rather difficult to distinguish from *Reophax* (Text-fig. 1). Ontogenetic considerations thus suggest that *Thomasinella* and *Reophax* are related and may have risen from the same ancestral stock. *Thomasinella* should then be placed in the Reophacidae.

THOMASINELLA AEGYPTIA Omara, n. sp.
Pl. 101, fig. 1–6, Text-fig. 1

Diagnosis.—Test uniserial or bifurcating in one plane; chambers nodulose, discoidal or polygonal and flattened; sutures either straight or chevron-shaped; wall simple, formed of rather angular sand grains, sometimes with a small amount of colored minerals; aperture either one or two terminal simple openings; length of holotype 1.9 mm., maximum breadth 0.88 mm.

Remarks.—A number of definite stages of individual development have been distinguished. The early stages are uniserial either rectilinear or gently curvilinear while the later ontogenetic forms are arborescent. The embryonic stage is sometimes shown by a fairly large megalospheric proloculus. Text-fig. 1 shows the ontogenetic relationship observed among different individuals of *Thomasinella aegyptia*.

Juvenile stage.—Description: A simple arrangement of uniserial chambers, straight or slightly curved; segments discoidal or nodulose; in the complete forms encountered the initial chamber is large, megalospheric; sutures distinct, slightly depressed, straight in the nepionic forms (Text-fig. 1–1a), with fine indentation or gently chevron-shaped in the neanic forms (Pl. 101, fig. 3,4, Text-fig. 1–2a,3a,4); wall arenaceous, simple, formed of sand grains mostly angular and of more or less uniform size; chamber cavities simple, separated by septal walls; surface moderately smooth; aperture terminal, simple, roughly rounded or polygonal opening surrounded by coarser sand grains (Text-fig. 1–1c,2b,3b). The length of the test and the number of the chambers are indefinite due to the fact that the test is seldom found complete. In the few complete tests observed, the length of the shell varies from 1.2, 1.6 to 2 mm. (Pl. 101, fig. 3).

TEXT-FIG. 2—*Thomasinella punica*, n.sp., longitudinal section ×10.

The juvenile forms have somewhat the appearance of *Reophax suevica* Franke (1936) but are roughly twice as large as that species.

Ephebic (adult) stage.—Description: Uniserial; chambers discoidal, later flattened and more broad than long with more or less polygonal outline; early sutures straight, later chevron-shaped; last-formed chamber large with two terminal slit-like apertures, trending parallel to the flattened part of the shell, surrounded by coarser sand grains (Text-fig. 1–5a,5c); wall arenaceous, simple.

The chevron-shaped septa and the two slit-like terminal apertures characterize this uniserial intermediate form. The simple cavity of the last-formed chamber is divided into two smaller ones by an internal partition (Text-fig. 1–5b), such a division is sometimes reflected on the surface by one or two faint depressions (shaded areas, Text-fig. 1–5a).

Gerontic (senile) stage.—Description: Test dichotomously branching, in the early

stages uniserial, later bifurcating; segments either discoidal or flattened with more or less polygonal outline; sutures straight or chevron-shaped, somewhat constricted; wall arenaceous, simple, thickness of wall around 2 mm., surface moderately smooth; cavities separated by the septal walls or otherwise connected; aperture either one roughly rounded sometimes polygonal or two slit-like apertures at the end of each branch (Text-fig. 1–6c,7b), bifurcation either starts consecutively (Text-fig. 1–7a) or after retrograding to the early uniserial arrangement; angle of bifurcation observed between twin branches varies from 75°, 87°, 92°, 94° (Pl. 101, fig. 1,2,5, Text-fig. 1–6a,7a,8a,9a, 10).

The senile stage of *Thomasinella aegyptia* is readily comparable with *Thomasinella punica* Schlumberger (Pl. 101, fig. 7–10). However the chief distinctions of the latter are:

1) Suture lines are usually only faintly marked.
2) At the end of each branch there is a conspicuous, comparatively larger, circular aperture.
3) The wall is formed by the agglomeration of very fine sand grains (Text-fig. 2).

Types.—AMNH, Holotype, pl. 101, fig. 6, FT-1151. Paratype, pl. 101, fig. 1, FT-1158, 2, FT-1159, 3, FT-1154, 4, FT-1155, 5, FT-1160. About 70 specimens were secured and 10 of these sectioned.

THOMASINELLA FRAGMENTARIA
Omara, n. sp.
Pl. 101, fig. 11

Diagnosis.—Uniserial or bifurcating; test formed of agglutinated fossil remains; other test parts are to a less extent of angular sand grains held together in a slightly calcareous whitish cement which is sometimes brownish and ferruginous; wall very thick and labyrinthic; surface very irregular and rough; sutures not distinct; aperture terminal simple at the top of the last chamber or chambers of the branches; maximum length of holotype 2.5 mm.; maximum breadth 1 mm.

Remarks.—The branching form of *Thomasinella fragmentaria* resembles *Thomasinella rugosa* Schlumberger but differs from that species in that it has more distinct sutures and definite terminal simple apertures.

Type.—AMNH, Holotype, pl. 101, fig. 11, FT-1161.

Genus CRIBROSTOMOIDES Cushman 1910
CRIBROSTOMOIDES SINAICA Omara, n.sp.
Pl. 102, fig. 4–6, Text-fig. 3–1,2, and 4a–c

Diagnosis.—Test free; planispiral; completely involute; umbilicate on both sides; outer coil consists of 5–7 triangular chambers increasing rapidly in size; sutures well-marked, depressed, slightly concave towards the aperture at about half the distance to the periphery, then gently convex; periphery broad, rather rounded, lobate; wall simple, finely arenaceous with considerable whitish calcareous cement. Aperture conspicuous, comparatively large in the form of a crescentic or inverted U-shaped opening in the apertural face of the last formed chamber, above the base.

Dimensions:

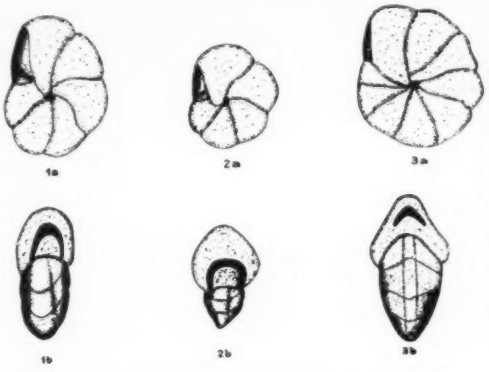
	Greater Diameter (mm.)	Lesser Diameter (mm.)	Thickness (mm.)
Holotype	0.91	0.74	0.51

Remarks.—1. Höglund (1947, p. 133, pl. 11, fig. 1–5) divided Cushman's genus *Haplophragmoides*, 1910, into a group with "interio-marginal" aperture and another with "interio-areal" aperture. The former group retains the generic name *Haplophragmoides* while the latter has been grouped under the new genus *Labrospira*.

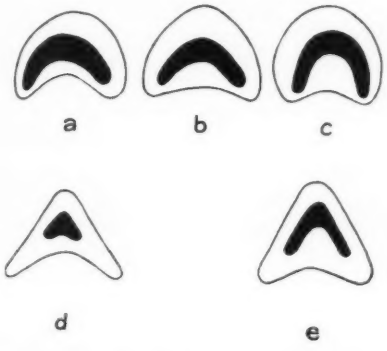
2. Frizzel & Schwartz (1950, p. 1,2, fig. 1) emended the genus *Cribrostomoides* Cushman, 1910, to include planispiral arenaceous foraminifera with undivided chambers and with either a slit aperture or, in variant individuals, with multiple apertures enclosed within the apertural face at its base "interio-areal" and thus rejected *Labrospira* Höglund, 1947, as synonym. The emendment of Frizzel is adopted here.

3. Rarely is an irregular crescentic aperture seen.

Types.—AMNH, Holotype, pl. 102, fig. 5,6, FT-1163. Paratype pl. 102, fig. 4 FT-1164. Some 100 specimens secured, 5 were sectioned.



TEXT-FIG. 3—*Cribrostomoides sinaica* n.sp. (*1a–2b*) ×22.
1a, side view; *1b*, apertural view (holotype)
2a, side view; *2b*, apertural view (paratype)
Cribrostomoides paralens (*3a–3b*) ×22
3a, side view; *3b*, apertural view.



TEXT-FIG. 4—Diagram showing a comparison between the apertures of *Cribrostomoides sinaica* (*a–c*) and *C. paralens* (*d*, *e*).

CRIBROSTOMOIDES PARALENS Omara, n.sp.
Pl. 102, fig. 1–3, Text-fig. 3–3 and 4d, 4e

Diagnosis.—Test free, lenticular, planispiral, completely involute, umbilicate on both sides; outer coil consists of 6–9 comparatively narrow triangular simple chambers; sutures conspicuous, gently sigmoidal; wall simple, finely arenaceous with a considerable amount of calcareous cement. Aperture inverted V-shaped, in the apertural face of the last formed chamber.

Dimensions:

	Greater Diameter (mm.)	Lesser Diameter (mm.)	Thickness (mm.)
Holotype	0.91	0.80	0.51

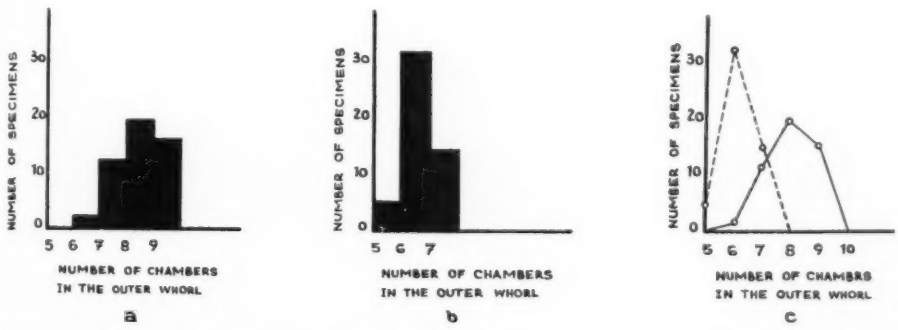
Remarks.—This species differs from *Cribrostomoides sinaica* in having a somewhat compressed lenticular test; the periphery tends to be angular while the inverted V-shaped aperture is situated somewhat higher in the apertural face (Text-fig. 4). The variation in number of chambers of the outer whorl in both *Cribrostomoides paralens* and *Cribrostomoides sinaica*, based on fifty specimens of each is elucidated by histograms and frequency curves (Text-fig. 5).

Types.—AMNH, Holotype, pl. 102, fig. 1,2, FT-1165. Paratype, pl. 102, fig. 3, FT-1166.

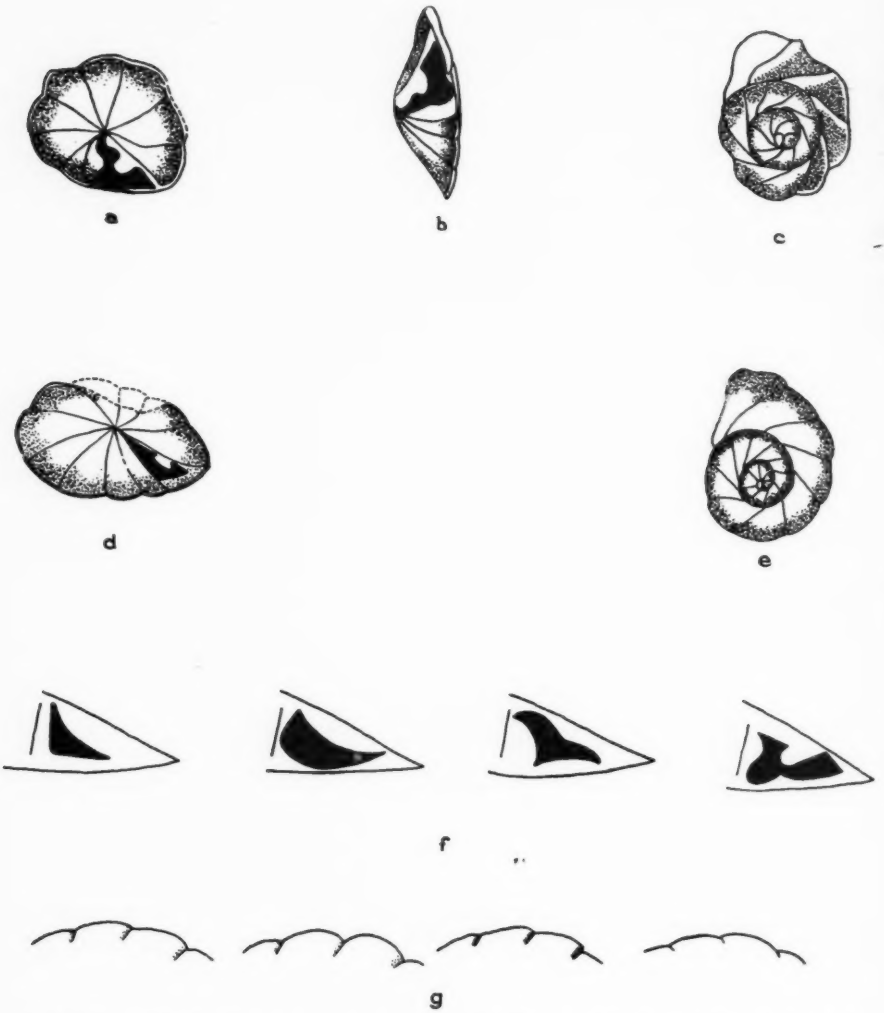
Genus NEZZAZATA Omara, n. gen.

Genotype: *N. simplex*, n. sp.

Diagnosis.—Test small, trochiform, planoconvex or unequally biconvex, ventrally



TEXT-FIG. 5—*a* & *b*. Histograms showing the variation in the number of chambers in the outer whorl of *Cribrostomoides sinaica* & *C. paralens* respectively. *c*. Frequency curves showing the variation in the number of chambers in the outer whorl of *Cribrostomoides sinaica* (continuous line) and *C. paralens* (dashed line).



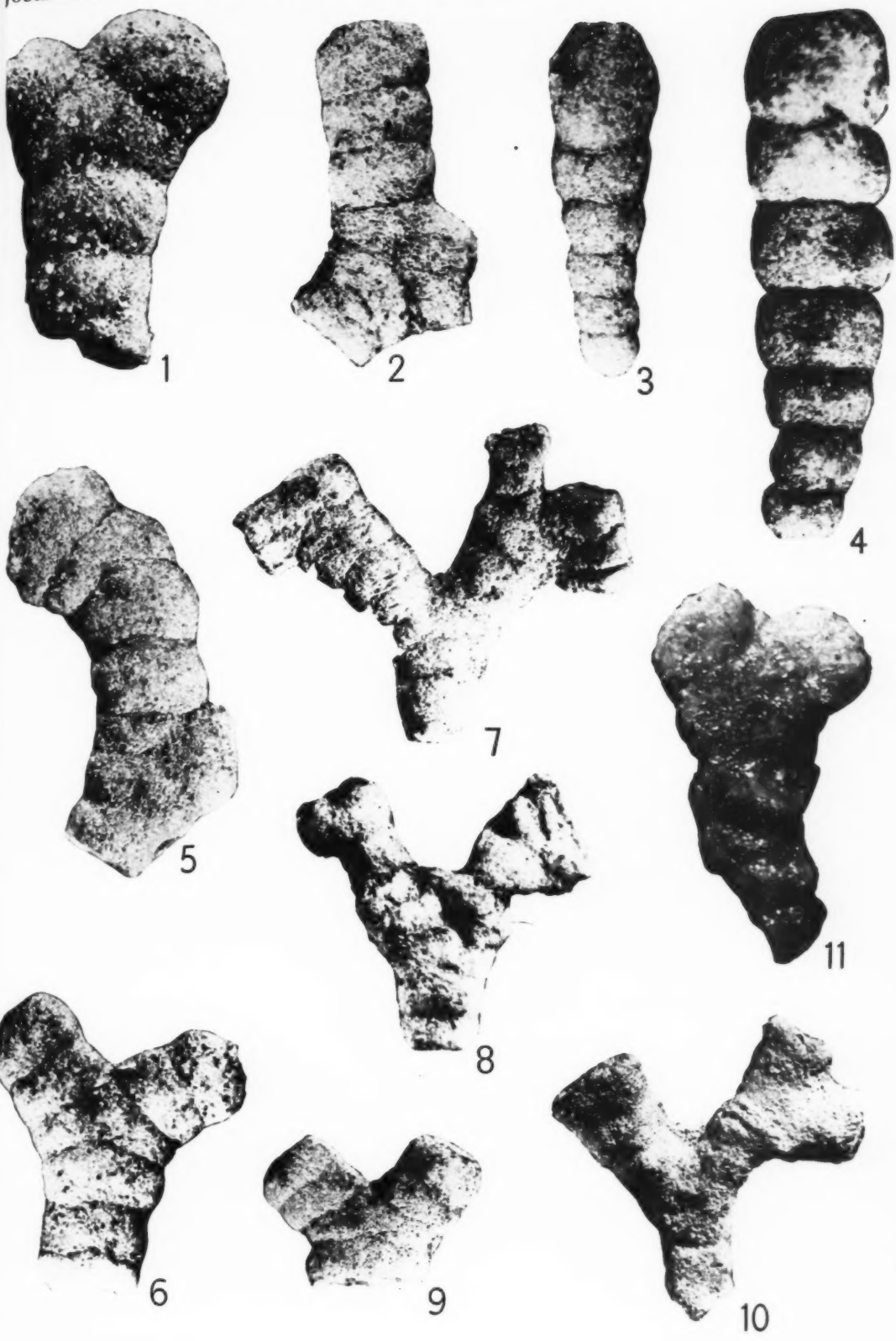
TEXT-FIG. 6—*Nezzazata simplex*, n. gen., n. sp. *a*, Ventral view; *b*, side view; *c*, dorsal view (holotype), ×38; *d*, ventral view; *e*, dorsal view (paratypes), ×38; *f*, diagram showing some variations in the aperture; *g*, diagram showing some patterns of lobulation in the periphery.

EXPLANATION OF PLATE 101

FIG. *1–6*—*Thomasinella aegyptia* Omara, n. sp. Lower part of Cenomanian, Nezzazat area, W. Sinai, Egypt, ×27. *6*, holotype.

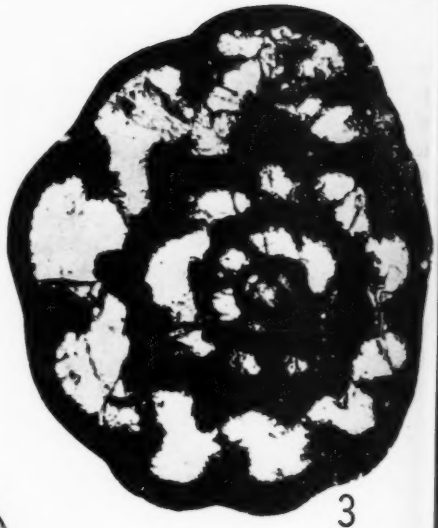
7–10—*Thomasinella punica* Schlumberger. Upper Cenomanian, Djebel Meghila (Foum el Guelta), Tunisia, ×15.

11—*Thomasinella fragmentaria* Omara, n. sp. Lower part of Cenomanian, Nezzazat area, W. Sinai, Egypt, ×23. Holotype.

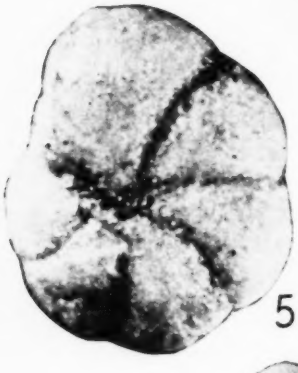

1
2
3
4
5
7
11
8
6
9
10

1

2


3

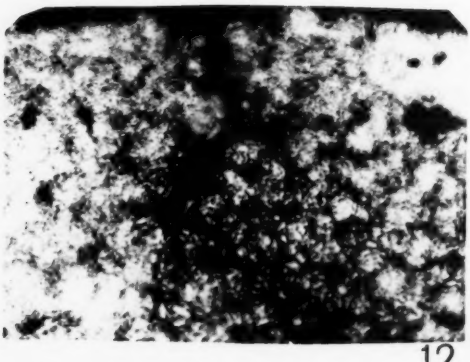
4


5

7

6

8


12

9

10

13

11

involute, dorsally evolute; three whorls, 8–10 chambers in each whorl; chambers without supplementary chamberlets. Apertural face triangular, either nearly vertical or inclined; aperture ventral, a narrow opening extending from near the umbilical region at the base of the apertural face bending below the dorsal wall parallel to the periphery, usually with a flattened tooth-like outgrowth of the wall of various shapes. Wall calcareous, granulate, single-layered, finely perforate; septa single-walled.

Remarks.—Wood (1949) and Glaessner (1949) emphasize the importance for classification, of the micro-structure of the wall of the test in the foraminifera, and in particular the discrimination between granulate and radiate structures. The micro-structure of the genus *Nezzazata* differs essentially from that described in *Rotalia* by Wood (1949) and that assigned to the superfamily Rotaliidea by Smout (1954, p. 9). The systematic position of genus *Nezzazata* and closely allied genera in relation to other rotaliid foraminifera is still to be settled.

NEZZAZATA SIMPLEX Omara n. sp.
Pl. 102, fig. 7–13, Text-fig. 6

Diagnosis.—Test free, small, trochoid; outline sub-circular to oval; ventrally convex, dorsally either slightly convex or nearly flat, sometimes uneven; three whorls with 8–10 chambers in each whorl; chambers distinct increasing slightly in size as added; ventral sutures radial slightly depressed and gently curved, in some cases with a gentle indentation which points backwards away from the apertural face, dorsal sutures nearly straight, oblique, faintly limbate; umbilical area closed; periphery usually acute; lobulation varies in pattern, rarely nearly smooth; appearance usually waxy white; wall single layered, granulate, finely perforate; septa single-walled; proloculus, about 0.05 mm. in diameter. Aperture ventral, long narrow opening extending from near the umbilical region at the base of the apertural face, bending below the dorsal wall parallel to the periphery, the bending is nearly at right angles to form an L-shaped orifice, typically with a flattened toothlike outgrowth of the wall which projects into the aperture opposite to the angle of bending.

Dimensions:

	Greater Diameter (mm.)	Lesser Diameter (mm.)	Thickness (mm.)
Holotype	0.62	0.51	0.23

Types.—AMNH, Holotype, pl. 102, fig. 7–9, FT-1167. Paratypes, pl. 102, fig. 10–13, FT-1168. About 200 specimens, 20 sectioned.

DISCUSSION

The different forms of *Thomasinella aegyptia* and *Thomasinella fragmentaria* occur together in the shales and marls of the lower part of the Cenomanian. Schlumberger (1893) recorded *Thomasinella punica* and *Thomasinella rugosa* from the "Cenomanien supérieur" in Tunisia and Algeria.

Cribrostomoides siniaca and *Cribrostomoides paralens* together with *Nezzazata simplex* are confined to a gray gypsiferous marl in the lower part of the Cenomanian where they are very abundant.

These faunas have not been found above the lower part of the Cenomanian of Nezzazat (Omara, 1951). This restricted range gives some expectation of the possible value for correlation but this must await additional work in other Cenomanian sections in Egypt to ascertain their regional extensions.

EXPLANATION OF PLATE 102

FIG. *1–3*—*Cribrostomoides paralens* Omara, n. sp. *1,2*, holotype, ×50; *3*, equatorial section, ×75. From lower Cenomanian, Nezzazat area, western Sinai, Egypt.

4–6—*Cribrostomoides sinaica* Omara, n. sp. *4*, median (equatorial) section, ×75; *5,6*, holotype, ×50. Same locality as above.

7–13—*Nezzazata simplex* Omara, n. sp. *7–9*, holotype, ×50; *10*, equatorial section, ×100; *11*, vertical section, ×300; *12*, part of equatorial section, ×750; *13*, part of vertical section, ×1000. Same locality as above.

Type locality.—The Nezzazat area, western coast of the Peninsula of Sinai (eastern coast of the Gulf of Suez), about 150 kms. southeast of Suez.

REFERENCES

BERMÚDEZ, P. J., 1952, Estudio sistmático de los foraminíferos rotaliformes: Venezuela, Dir. Geol., Boll. Geol., vol. 2, no. 4, 230 p., 35 pl.

BROTZEN, FRITZ, 1942, Die Foraminiferengattung *Gavelinella* nov. gen. und die Systematik der Rotaliiformes: Sverig. geol. Unders. Årsbok, vol. 36, no. 8, ser. C, no. 451, p. 1–60, pl. 1.

CUSHMAN, J. A., 1948, Foraminifera, their classification and economic use. 605 p., Harvard Univ. Press.

ELLIS, B. F., & MESSINA, A. R., 1940–1955, Catalogue of Foraminifera. Amer. Mus. Nat. Hist.

FRANKE, ADOLF, 1936, Die Foraminiferen des deutschen Lias: Preuss. Geol. Landesanstalt, Abh., N.F., Heft 169, p. 1–138, Taf. 1–12.

FRIZZEL, D. L., & SCHWARTZ, ELY, 1950, A new lituolid foraminiferal genus from the Cretaceous, with an emendation of *Cribrostomoides* Cushman: Missouri School Mines Metallurgy, Bull. tech. ser., no. 76, p. 1–12, 1 pl.

GLAESSNER, M. F., 1949, [Discussion of Alan Wood's paper on the structure of the wall of the test in the Foraminifera; its value in classification]: Geol. Soc. London, Quart. Jour., vol. 105, p. 539–540.

HÖGLUND, HANS, 1947, Foraminifera in the Gullmar Fjord and the Skagerak: Uppsala Univ., Zool. Bidrag, Bd. 26, p. 1–328, 32 pl.

OMARA, S. M., Micro-stratigraphical studies of the Cretaceous rocks of Nezzazat area. (Eastern Coast of the Gulf of Suez, Egypt), unpubl. M.Sc. thesis, Univ. of Cairo, 1951.

PERON, ALPHONSE, 1893, Description des Brachiopodes, Bryozaires et autres invertébrés fossiles des terrains Crétacés de la region sud des hauts-plateaux de la Tunisie, recueillis en 1885 et 1886 par M. Phillippe Thomas. In exploration scientifique de la Tunisie, Paris, Imprimerie Nationale, p. 393–395.

SMOUT, A. H., 1954, Lower Tertiary Foraminifera of the Qatar Peninsula: British Museum (Natural History), ix+96 p., 15 pl.

SCHLUMBERGER, CHARLES, 1889, [Sur le genre *Thomasinella* Schlumberger]: Bull. Soc. Géol. France, sér. 3, t. 17, p. 425.

——, 1893, Description de quelques fossiles nouveaux ou critiques des terrains tertiaires et secondaires de la Tunisie recueillis en 1885 et 1886 par M. Phillippe Thomas. In exploration scientifique de la Tunisie, Imprimerie Nationale, p. 5–6.

WOOD, ALAN, 1949, The structure of the wall of the test in the Foraminifera; its value in classification: Geol. Soc. London, Quart. Jour., vol. 104 (1948), p. 229–255, pl. 13–15.

JOURNAL OF PALEONTOLOGY, VOL. 30, NO. 4, p. 891–958, 101 TEXT-FIG., JULY, 1956

TERTIARY FORAMINIFERA OF COASTAL ECUADOR: PART II, ADDITIONAL NOTES ON THE EOCENE SPECIES

J. HOFKER
Scheveningselaan 157, The Hague, Holland

ABSTRACT—A re-study of the Eocene Foraminifera of coastal Ecuador, using more refined techniques than before, has resulted in numerous changes and additions to the faunal list given in Part I of this report. Three new genera are described: *Spirobolivina*, *Stainforthia* and *Parrelloides*; 29 species are added to the previous list, eight of them as new species; 39 re-determinations are made, including recognition of a further eight new species or new names. The revised list, presented on distribution charts, contains 147 named species.

INTRODUCTION

IN 1951, J. A. Cushman & R. M. Stainforth published a list of localities for 59 zonal units recognizable in the Tertiary of coastal Ecuador, with a systematic description of the Foraminifera found in the Eocene sediments. The death of Cushman and other circumstances prevented further study of the foraminiferal faunas, so the present author took over the project. This re-study has resulted in numerous changes and additions to the faunal inventory given by Cushman & Stainforth. There are several new definitions and introductions including the following:

New genera

Spirobolivina (genotype: *Bolivinopsis pulchella* Cushman & Stainforth)
Stainforthia (genotype: *Virgulina concava* Höglund)
Parrelloides (genotype: *Cibicides hyalinus* Hofker)

New species

Angulogerina ecuadorensis
Bulimina pseudovata
Cassidulina sublaevigata
Eponides? anconensis
Frondicularia subhunteri
Globigerina stainforthi
G. paratriloculinoides
G. paravenezuelana
G. protoreticulata
G. pseudocretacea
Nummulites hyalinus
Lepidocyclina ecuadorensis
Schenckiella fragilis
Sigmoilina ecuadorensis
Stainforthia dalliformis
Stilostomella? costata

New names

Nonion brunatus
Nonionella stainforthi
Valvulineria stainforthi

New families

Gavelinellidae
Globobuliminidae
Parrelloididae

The considerable number of changes and additions to the faunal list given by Cushman & Stainforth for the same material is due to the development of a new classification. This procedure involves fine details of the foraminiferal test which were ignored in older systems. In the new classification, special attention is paid to the character of the wall of the test, the spacing and type of pores, the presence of subsidiary apertures, the presence and structure of toothplates in the apertures, the nature of the septal walls, and other fine details of internal structure. On such a basis, it is possible to demonstrate major differences between forms which appear similar on casual inspection at low magnification, and to recognize closely-knit series of species and genera. The natural family groups based on this classification differ markedly from the Cushman classification; e.g., *Nonion* and *Elphidium* show important differences, whereas *Globigerina* and *Gümbelina* appear closely related; the Cassidulinidae fall close to the Buliminidae and have nothing in common with the Rotaliidae; Cushman's Anomalinidae and Heterohelicidae are polyphyletic units. Comments on the family relationships which have become clear in the course of these studies are included in the systematic descriptions.

The basic technique which has led to these somewhat revolutionary concepts involves examination of the Foraminifera under a clarifying oil, instead of in dry air. Each specimen is placed under a glass slide

in a drop of castor oil. This oil displaces air and greatly clarifies the test, so that much of the fine internal structures become visible. For ease of manipulation the specimen may be attached (still under oil) to a speck of Canada balsam. Magnifications of 170× to 630× are normally used. Studies of the tests *in toto* are checked and amplified by grinding sections on a fine Solenhofen stone.

Many of the determinations and descriptions of Cushman & Stainforth (1951) are accepted without comment, as indicated on accompanying distribution charts. The author wishes to thank R. M. Stainforth and Hans E. Thalmann for corrections and rewriting of the manuscript as well as helpful suggestions as to taxonomic details.

NOTES ON STRATIGRAPHY

Original localities and stratigraphic relationships of the 12 Eocene faunas, have been stated by Cushman & Stainforth (1951). These "units" are variable as to the number of species of Foraminifera occurring in them (see accompanying charts). The largest numbers are recorded in units 5, 6, and 7 (57, 69, and 61 species respectively) of the neritic facies, in which Radiolaria are extremely scarce. In the Radiolaria-rich facies, units 9, 11, and 12, the foraminiferal species recorded number 22, 11 and 29 respectively. The additional six units, referred to brackish, sublittoral, and reefal facies, contain from one to 20 species of smaller Foraminifera.

A point of interest in the faunas is that the planktonic Foraminifera, mostly *Globigerina* spp., differ appreciably from the usual suite found in the Caribbean Eocene. The author suggests that this difference indicates that an Antarctic fauna has been transported northwards by oceanic currents. The presence of such currents has already been postulated to explain the dominance of a radiolarian facies in the Ecuador Eocene (Stainforth, 1948, p. 137–139). The faunas of units 4 and 10, classified by Cushman & Stainforth as reefal and sublittoral, have a resemblance with those in sediments of the Flysch of Bukowiecz.

Cushman & Stainforth described unit 2 as belonging to the upper Cretaceous. However, the samples contain several foraminiferal species which are not Cretaceous but typically Lower Tertiary: *Globigerina paratrilocullinoides*, n. sp. *Anomalinoides acutus* (Plummer), and *Spiroplectammina nutalli* Lalicker. *Anomalinoides acutus* occurs also in the Paleocene of Holland and Sweden. R. M. Stainforth now believes that this fauna is Paleocene (personal communication). Locality 2 is west of Portoviejo, not east as stated (1951, p. 134).

Species which appear to be most representative of the Ecuador Eocene are as follows:

(present in six or more of the 12 faunas studied)
- *Bolivina maculata*
- *Bolivina jacksonensis*
- *Neouvigerina mantaensis*
- *Parrelloides cookei*
- *Robulus limbosus*
- *Valvulineria stainforthi*
- *Valvulineria mississippiensis*

(present in five of the faunas)
- *Buliminellita mirifica*
- *Cassidulina globosa*
- *Gavelinonion chiranus*
- *Gavelinopsis perlucida*
- *Neouvigerina chirana*
- *Stilostomella* (?) *curvatura*
- *Valvulineria subbadenensis*

Other species, though present in fewer samples, may assist in the division of the Eocene. Some of them give important clues for regional correlation, e.g., *Anomalinoides acutus*, *Bolivina gracilis*, *Bolivina carinata*, *Cancris cocoaensis*, *Gyroidinoides chiranus*, *Liebusella byramensis*. *Gavelinion chiranus*, *Osangularia mexicana*, *Rotaliatina mexicana*. *Euuvigerina gardnerae*, *Euuvigerina glabrans*, and *Valvulineria texana* have been described from the Eocene of other countries.

DISPOSITION OF TYPES

Type material of the new and re-named species has been deposited in the Cushman Collection at the U. S. National Museum. They have been catalogued by A. R. Loeblich, Jr., and given numbers P4902-P4920. Some of the more common material has been stored at the Geological Survey, Haarlem, Netherlands, the Amt für Bodenforschung, Hannover, Germany, and Harvard University.

SYSTEMATIC DESCRIPTIONS

Family VALVULINIDAE

A careful analysis of this arenaceous family by the writer has shown that many species and genera hitherto included in the

TABLE 1.—DISTRIBUTION OF THE PRINCIPAL FORAMINIFERA IN EOCENE TYPE-LOCALITIES OF COASTAL ECUADOR

AGE	Paleocene	Middle Eocene			Upper Eocene								
Type Locality No.	2	1	3	4	5	6	7	8	9	10	11	12	13
ASTRORHIZIDAE													
Rhabdammina eocenica			×			×			×				
Rhabdammina samanica			×				×		×				
RHIZAMMINIDAE													
Bathysiphon eocenica						×	×		×				
SACCAMMINIDAE													
Psammosphaera eocenica											×	×	
Technitella archaeonitida			×						×			×	
AMMODISCIDAE													
Ammodiscus incertus						×	×		×				
LITUOLIDAE													
Haplophragmoides carinatus			×				×	×	×				
Cyclammina pacifica			×			×	×						
TEXTULARIIDAE													
Spiroplectammina nuttalli						×							
Spiroplectammina eocenica			×										
Ammospirata mexicana								×					
Vulvulina chirana						×	×						
VALVULINIDAE													
Schenckiella fragilis					×		×						
Karreriella contorta?						×							
Karreriella nuttali						×	×					×	
Feravina coralliformis				×					×				
MILIOLIDAE													
Sigmoilina tenuis					×	×	×				×	×	
Sigmoilina ecuadorensis				×									
Spiroloculina jarvisi					×	×	×				×		
Quinqueloculina orbiculata						×							
Quinqueloculina spp						×							
Triloculina carinata						×	×						
Pyrgo danvillensis						×	×						
Pyrgo pseudoinornata						×							
LAGENIDAE													
Lenticulina (Robulus) coaledensis										×			
L. (R.) inusitata					×								
L. (R.) carolineana						×							
L. (R.) limbosa				×	×	×	×	×				×	
L. (R.) gutticostata													×
L. (R.) insueta					×								
L. (R.) chirana						×							
Nodosaria chirana				×	×	×	×						
Frondicularia subhunteri					×								
Stilostomella ? costata					×								
Stilostomella ? curvatura					×								
Stilostomella verneuili					×								
Stilostomella cocoaensis					×								
Stilostomella gracillima			×				×		×			×	
Plectofrondicularia vaughani						×	×						
Plectofrondicularia dentifera					×								
Plectofrondicularia cookei					×	×							
P. packardi multilineata					×								
Amphimorphina spp.							×						
Planularia clara					×								
Pseudoglandulina laevigata						×	×						
Pseudoglandulina turbinata						×							
Saracenaria hantkeni					×								
Vaginulina saundersi						×							
Lagena spp.					×	×	×						
POLYMORPHINIDAE													
Globulina minuta						×							
Sigmomorphina trinitatensis						×	×					×	

TABLE 1—*Continued*

AGE	Paleocene	Middle Eocene			Upper Eocene								
Type Locality No.	2	1	3	4	5	6	7	8	9	10	11	12	13
GLOBOBULIMINIDAE													
Stainforthia dalliformis					×								
Stainforthia venezuelana					×								
Protoglobobulimina decurtata					×	×	×	×					
Globobulimina oregonensis						×		×		×			
BOLIVINIDAE													
Bolivina carinata							×					×	
Bolivina basisenta					×	×							
Bolivina jacksonensis			×		×	×	×	×	×	×			
Bolivina maculata		×	×		×		×	×	×	×		×	
Bolivina mexicana							×						
Bolivina byramensis							×						
Bolivina gracilis							×						
Bolivinoides alazanensis							×			×			
Spirobolivina pulchella					×	×	×						
BULIMINIDAE													
Praebulimina jacksonensis					×	×	×		×				
Bulimina cacumenata					×								
Bulimina lineata						×	×					×	
Bulimina pseudovata					×		×					×	
Bulimina secaensis					×								
Bulimina peruviana			×					×					
Bulimina impendens						×	?						
Bulimina semicostata		×											
Bulimina acutangularis						×							
BULIMINELLIDAE													
Buliminella obesa					×								
Buliminella chirana								×	×				
Buliminella peruviana			×			×	×	×					
Buliminellita mirifica					×	×	×	×	×				
Buliminellita nuda					×								
UVIGERINIDAE													
Euuvigerina glabrans							×						
Euuvigerina gardnerae					×								
Euuvigerina yazooensis					×			×		×		×	
Euuvigerina coccaensis				×				×			×		
Euuvigerina cookei								×					
Neouvigerina mantaensis		×		×	×	×					×	×	
Neouvigerina chirana					×	×	×		×	×		×	
Angulogerina ecuadorensis												×	
CASSIDULINIDAE													
Cassidulina crassa						×							
Cassidulina cf. C. subglobosa				×	×	×	×						
Cassidulina globosa				×	×	×	×						
Cassidulina sublaevigata						×			×			×	
Cassidulinoides howei										×			
Stichocassidulina thalmanni					×		×					×	
ELLIPSOIDINIDAE													
Pleurostomella obesa						×							
Pleurostomella acuta												×	
Pleurostomella ecuadorana												×	
Ellipsoglandulina labiata								×					
NUMMULITIDAE													
Nummulites hyalina								×		×			
AMPHISTEGINIDAE													
Asterigerinoides crassaformis								×	×		×	×	
Helicostegina (Tremastegina?) elliotti		×											
CIBICIDIDAE													
Cibicides cicatricosus								×					
Cibicides cooperensis								×					
Cibicides lobatulus?						×							
C. americanus antiquus								×					

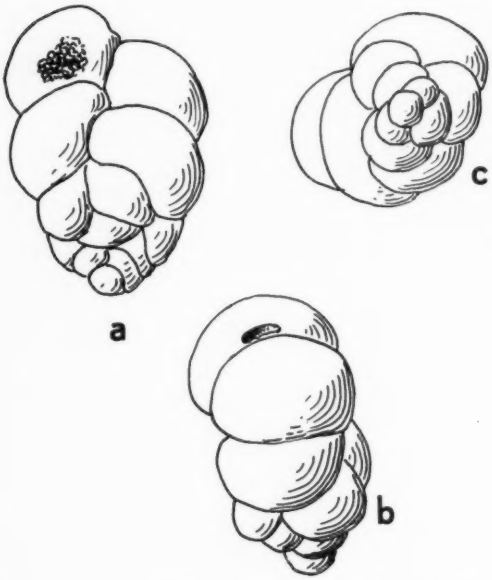
TABLE 1—*Continued*

AGE	Paleocene	Middle Eocene			Upper Eocene								
Type Locality No.	2	1	3	4	5	6	7	8	9	10	11	12	13
PARRELLOIDIDAE													
Parrelloides cookei				×	×	×	×		×			×	
Osangularia mexicana						×	×						
Planulina mexicana					×	×							
P. cocoaensis cooperensis							×						
CHILOSTOMELLIDAE													
Allomorphina trigona					×	×					×		
Chilostomelloides oviformis					×	×	×		×				
Pullenia duplicata vars.						×	×	×	×				
Pullenia alazanensis					×							×	
ANOMALINIDAE													
Anomalinoides acuta	×												
Anomalina? alazanensis spissiformis						×							
Anomalina mississippiensis ocalanus		×				×	×					×	
TINOPORIDAE													
Lepidocyclina ecuadorensis				×									
NONIONIDAE													
Nonion danvillense					×								
Nonion peruvianus					×								
Nonion brunatus					×						×		
Nonion planatus						×							
Nonionella stainforthi					×	×	×	×					
Nonionella hantkeni vars.							×			×			
VALVULINERIIDAE													
Valvulineria stainforthi		×	×	×	×		×		×	×		×	
Valvulineria subbadenensis							×	×					
Valvulineria samanica					×								
Valvulineria texana						×	×						
V. peruviana discrepans						×	×						
Valvulineria eocenica						×	×						
Valvulineria crenulata					×		×	×					
ALABAMINIDAE													
Gyroidinoides girardanus						×	×		×				
Gyroidinoides chiranus					×								
Gyroidinoides scalatus						×							
Gyroidinoides planatus						×							
Gyroidinoides octocameratus					×	×	×		×			×	
Rotaliatina mexicana					×								
GAVELINELLIDAE													
Gavelinella pompilioides						×							
Gavelinopsis perlucida		×	×	×	×		×					×	
Gavelinonion chiranus					×	×	×		×			×	
MARGINOLAMELLIDAE													
Cancris cocoaensis				×		×	×	×		×		×	
EPONIDIDAE													
Eponides? anconensis				×								×	
Eponides umbonatus				×		×	×		×			×	
Eponides minimus						×	×					×	
Epistomina eocenica			×			×	×						
GLOBIGERINIDAE													
Globigerina danvillensis						×	×						
Globigerina paravenezuelana				×			×						
Globigerina protoreticulata				×								×	
Globigerina stainforthi				×									
Globigerina pseudocretacea				×		×				×	×	×	
G. paratriloculinoides	×												
Hantkenina primitiva				×	×	×							
Gümbelina (Heterohelix) navarroensis												×	
Hastigerinella spp.		×								×	×	×	

Valvulinidae do not belong. The type genus of the family is *Valvulina*, and all true species of that genus show a typical toothplate and pores in the arenaceous test, hence only those genera which show these fundamental features can properly be included in the family. Similar genera, related to *Eggerella*, which show no toothplate and no pores in the walls should probably be placed in a distinct family. True Valvulinidae includes: *Valvulina, Karreriella, Clavulina, Marssonella, Valvotextularia, Valvopavonina, Bolivinitella, Schenckiella, Dictyoconus, Cymbalopora* and *Ferayina*. In *Dictyoconcus* and *Ferayina*, the toothplate has formed the large horizontal plates covering the center of the ventral side of the test. *Eggerella, Dorothia, Goësella, Tritaxilina, Liebusella, Ataxophragmium* and probably *Textulariella* are placed in the Eggerellidae.

Genus KARRERIELLA Cushman, 1933
KARRERIELLA NUTTALLI (Cushman & Stainforth)
Text-fig. 1

Plectina dalmatina NUTTALL [not Liebus], 1935, Jour. Paleont., vol. 9, p. 123, pl. 14, fig. 8.



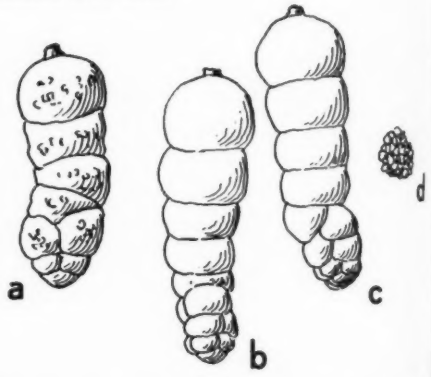
TEXT-FIG. *1—Karreriella nuttalli* (Cushman & Stainforth). (*a*) biserial aspect, part of wall sketched in to show fine pores between agglutinated particles; (*b*) side view, showing aperture; (*c*) showing initial chambers. From unit 6, all ×80.

Plectina nuttalli CUSHMAN & STAINFORTH, 1951, ibid., vol. 25, p. 144, pl. 25, fig. 26,27.

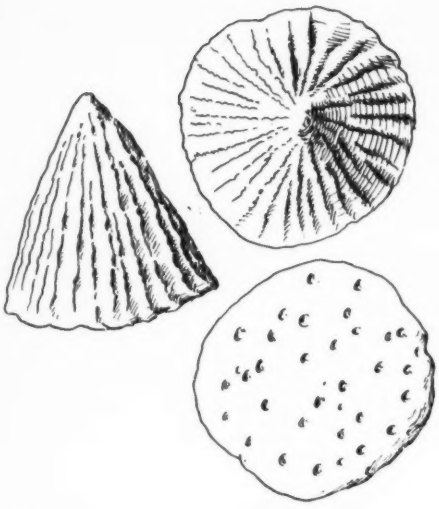
This species, described from localities 6, 7 and 12, was studied carefully. The wall is very finely arenaceous. In the megalospheric generation (the only generation found) the test begins with four chambers in a whorl, then becomes triserially arranged, and finally biserial. The aperture is not terminal, but always in the sutural area, a narrow slit with rounded ends. All these characters point to the genus *Karreriella* and not to *Plectina*. Moreover, in well preserved specimens fine protopores can be seen between the grains of the test. There is no doubt as to the taxonomy of this species; it is a true *Karreriella*.

Genus SCHENCKIELLA Thalmann, 1942
SCHENCKIELLA FRAGILIS Hofker, n. sp.
Text-fig. 2

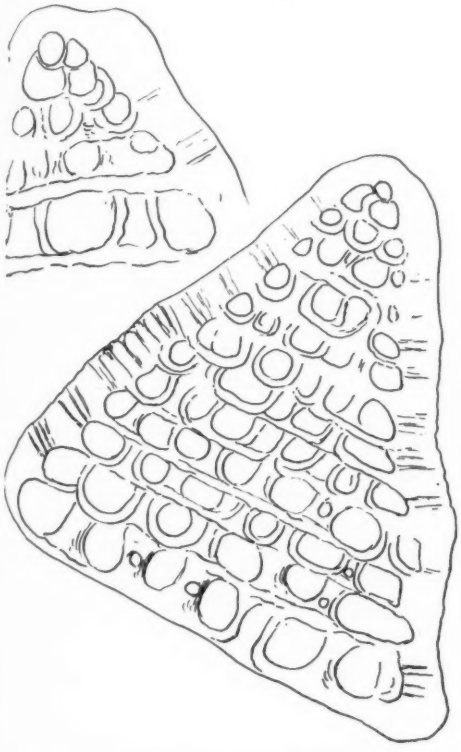
Several specimens of this species were found at localities 5a and 7. The test consists of a short biserial part which is preceded by a single whorl of four chambers, and followed by four or five uniserial chambers. The biserial part is only slightly broader than the uniserial part. The sutures are distinct, becoming depressed between the uniserial chambers, which are broader than high. The final chamber shows a distinct neck on which the small, rounded aperture is situated. The walls are very finely arenaceous, with fine protopores which are barely visible between the grains. Length up to 0.50 mm., breadth about 0.15 mm.



TEXT-FIG. *2—Schenckiella fragilis*, n. sp. (*a* holotype, ×80; (*b,c*) two views of a specimen from unit 7; (*d*) detail of the wall, showing pores between the sand grains, ×230.



TEXT-FIG. 3—*Ferayina coralliformis* Frizzell. Three views of a specimen from unit 4, ×65.



TEXT-FIG. 4—*Ferayina coralliformis* Frizzell. Sections of the same specimen shown in Text-fig. 3, ×180 and ×270. Showing the initial trochoid spire, and opeinngs in the "pillars."

Type locality.—In sea cliffs at Punta Mambra, southwest Ecuador. Type level: Seca formation, Upper Eocene. Type specimens have been deposited in the Cushman Collection, U. S. National Museum P4903 (2 specimens).

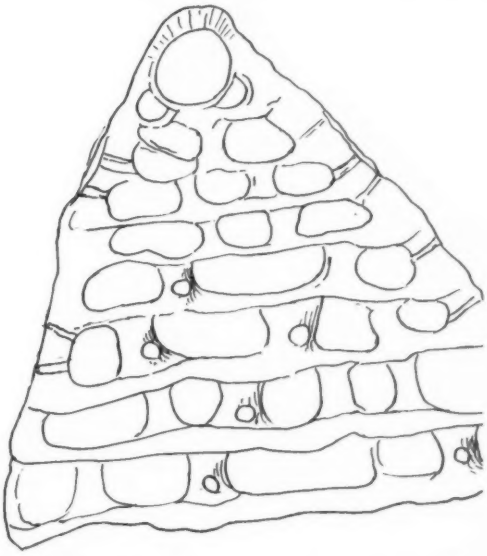
Genus FERAYINA Frizzell, 1949

FERAYINA CORALLIFORMIS Frizzell

Text-fig. 3–7

Ferayina coralliformis FRIZZELL, 1949, Jour. Paleont., vol. 23, p. 481–495, fig. 1–4.
Ferayina peruviana FRIZZELL, 1949, ibid., vol. 23, fig. 7. CUSHMAN & STAINFORTH, 1951, ibid., vol. 25, p. 159.

This peculiar foraminifer has been accurately described by Frizzell in 1949.



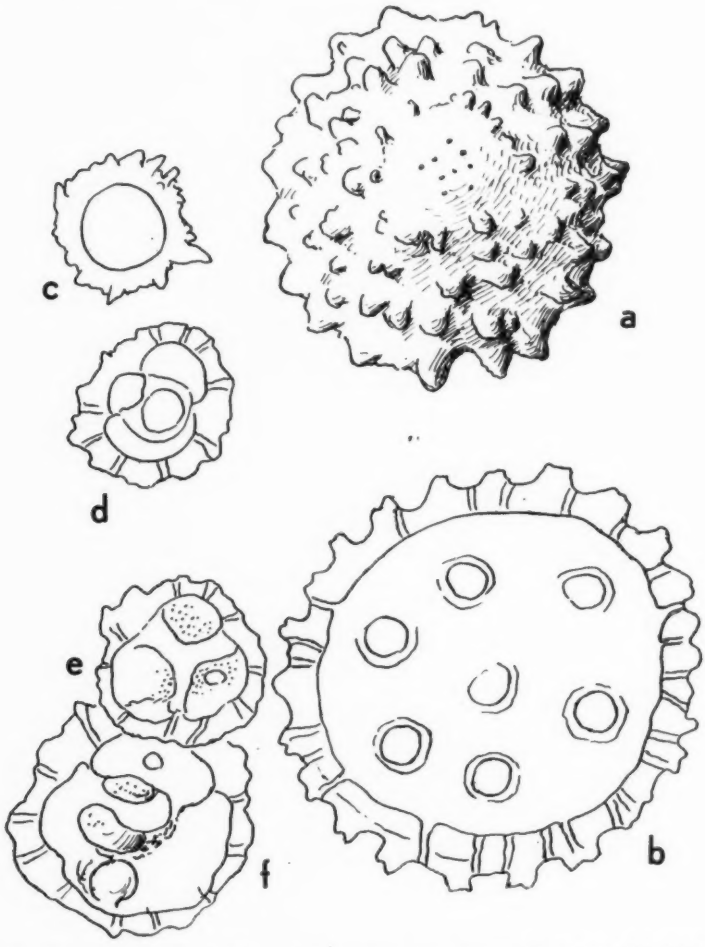
TEXT-FIG. 5—*Ferayina coralliformis* Frizzell. Section of topotype with very large proloculus, ×180

Frizzell comes to the conclusion that one lineage from an ancestral rotaliid form leads through *Ferayina* to *Chapmanina*, whereas a second, quite different, lineage leads from *Arenobulimina*, *Lituonella* and *Coskinolina* to *Dictyoconus*.

Frizzell further points out that the very peculiar inner structure of *Ferayina coralliformis* disproves Cushman's classification of the *Chapmanina* lineage in the neighborhood of the Cymbaloporidae. Frizzell kindly sent me eight well-preserved specimens of *F. coralliformis* and thin-sections were ob-

tained, ground in several directions across the tests.

There are two distinct forms in the material, small specimens with a height of about 0.17 mm., and apical angle of about 55°, a proloculus with a diameter of about 13μ, and six to eight uniserial chambers; and larger specimens, height about 0.26 mm. (up to 0.36 mm., *fide* Frizzell), apical angle about 65°, proloculus diameter about 35μ, and usually seven uniserial chambers. Thus the average height of the uniserial chambers in the larger form is greater than in the smaller type. It seems likely that these two forms are the A_1 and A_2 generations respectively. The initial part, observed under high magnification, even in the prolocular area shows distinct pores (somewhat smaller than on the uniserial chambers), and is covered with irregular buds of test material which, in the broader parts of the test, fuse together to form the typical longitudinal ribs described by Frizzell. External observation of the broader part of the test, which is often abraded, shows distinct pores. However, sectional views, especially in the more initial parts of the test, show these pores closed at the outer surface by a clear, thin layer of test material, and in one very well preserved specimen



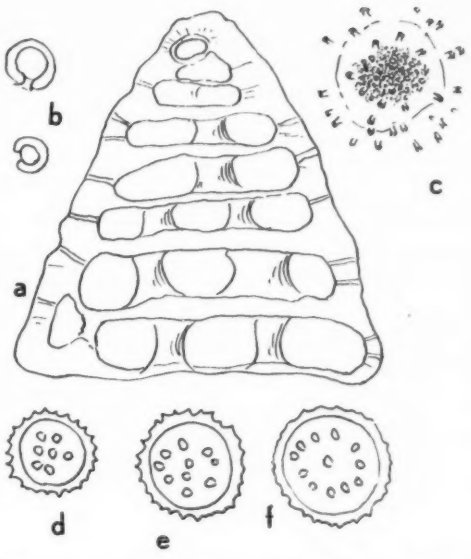
TEXT-FIG. 6—*Ferayina coralliformis* Frizzell. Topotype specimens. (*a*) view of initial part, showing some pores; (*b*) transverse section showing pillars and external pores; (*c,d,e,f*) serial sections from initial part towards base, showing the initial coiling of the chambers. All ×345.

all of these pores were closed. Therefore they can not be homologous with the pores of the calcareous Foraminifera, in which, conversely, a sealing layer is often found covering the inner lumen of a chamber, but never at the outside.

As Frizzell has pointed out, the lamellae between the successive uniserial chambers are without pores except for the large openings connected with the very typical hollow pillars. But when test-material of the outer walls and the septa is compared under high magnification, they are seen to be identical. These parts of the test consist of a hyaline mass of calcitic material, in which are embedded very fine particles of mineral matter insoluble in acid, probably siliceous. This type of test-material is known in many other Foraminifera, for instance *Schenckiella* and *Bolivinitella* but never in real calcareous forms.

A careful study was made of the initial part of the test. In all cases the proloculus was followed by three or four somewhat irregular chambers, connected with one another by large openings in the very thin walls. Then a much larger chamber is added, almost spanning the test and leading to the uniserial development which follows. Thus the initial set of chambers is very abnormal for a rotaliid genus. They cannot be compared with the initial chambers of the Cymbaloporidae, which show the features typified by *Conorboides* (see Hofker, 1950) with definite, though reduced, toothplates. In *Ferayina* these initial chambers are quite similar in all features to those described by Henson (1948) for the Lituolidae, Orbitolinidae and Meandropsinidae. The possibility of a close relationship between *Ferayina* and these advanced Valvulinidae is strongly enhanced by Henson's observation of a pore-bearing sub-epidermal layer closed by a thin, poreless "epidermis."

The conclusion of this investigation is that *Ferayina* is a true valvulinid genus, closely allied to *Dictyoconus* but not to the Rotaliiformes. The pores are homologous with those of *Valvulina* and closely allied genera. The test, though calcareous, in its finer structure shows affinities to the arenaceous Foraminifera and fine particles of foreign matter are enclosed in the calcite. The structure of the pillars and the megalospheric initial chambers can be seen again in highly developed valvulinid genera, but not in the Rotaliidae.



TEXT-FIG. 7—*Ferayina coralliformis* Frizzell. Topotype specimens. (*a*) longitudinal section through a small specimen; (*b*) two sections through "pillars" showing the openings in their walls; (*c*) top view of clarified specimen, showing agglutination and pores; (*d,e,f*) serial sections through an individual. *a–c*, ×290; *d–f*, ×65.

Frizzell described *Ferayina peruviana* as a separate species, on the basis of a single specimen, differing from *F. coralliformis* in the following characters: "It is considerably larger and has a larger angle of the test. Its longitudinal ribs are finer, more widely spaced, and more numerous. and increase in number by branching rather than by intercalation. In addition *F. peruviana* has more numerous apertures than the genotype."

Specimens of *Ferayina* from locality four, Ecuador, match Frizzell's description of *F. peruviana*, being somewhat larger and more mature than the Texas specimens. The largest specimens of *F. coralliformis* show seven to eight uniserial chambers, whereas a specimen from Ecuador has eleven uniserial chambers. The number of apertures is correspondingly higher, since the ventral surface of an eleventh chamber exceeds that of an eighth chamber. The apical angle is not appreciably different, being

50–65° in *F. coralliformis*, from Peru, 50–55° in the Ecuador specimens. The ribs of the Ecuador specimens number 11–12 round the apex, increasing to 33–34 at the base; in *F. coralliformis* from Peru the corresponding figures are 16–18 increasing to 30. Intercalation and branching of the ribs is seen in both sets of specimens, with branching more prominent in the later stages of growth. The internal structure is the same in all respects. On this evidence *Ferayina peruviana* is therefore a synonym of *F. coralliformis*. It was noticed that the sharpness of the apical angle varies inversely with the size of the proloculus; the holotype of "*peruviana*" represents possibly a microspheric individual of *F. coralliformis*.

The species was found at localities 4 and 9. In both cases nummulites and orbitoids were also present, suggesting that the genus preferred a reef habitat.

Family MILIOLIDAE

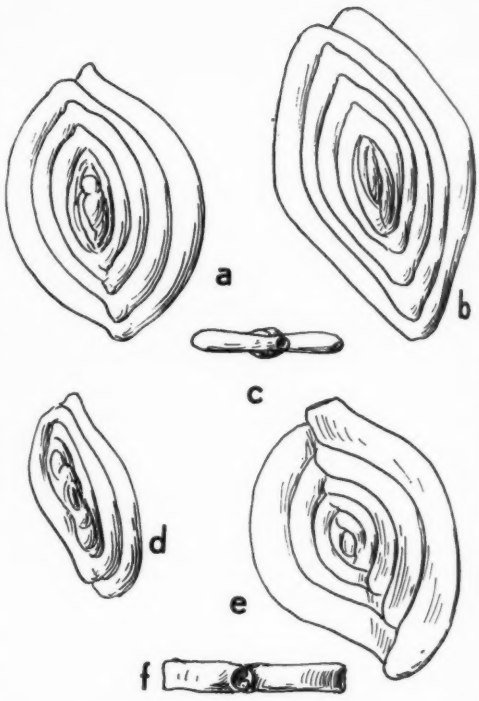
The group of the Miliolidae contains a variety of different forms, but they all have in common the same fine texture of the tests, namely monocrystalline in polarized light. They share this character with the otherwise unrelated Peneroplidae. One large group of the Miliolodae, in transverse section, has chambers with their inner wall formed by the wall of a earlier chamber; another large group possesses chambers with separate inner walls. Many species of this latter group have a tooth in the aperture, connected to a porous plate over the aperture (e.g. *Miliola*). This group also contains very highly developed genera such as *Flosculina*.

Genus SIGMOILINA Schlumberger, 1887
SIGMOILINA TENUIS (Czjzek)
Text-fig. 8,a–d.

Quinqueloculina tenuis CZJZEK, 1848, Naturw. Abh., Wien, Bd. 2, Abth. 1, p. 149, pl. 13, fig. 13–34.

Sigmoilina tenuis CUSHMAN & TODD, 1945, Cushman Lab. Foram. Res., Spec. Publ. 15, p. 10, pl. 2, fig. 4; CUSHMAN & STAINFORTH, 1951, Jour. Paleont., vol. 25, p. 145, pl. 25, fig. 35.

This species was found at localities 5, 6, 7, 11 and 12. The biserial part may be so highly developed that a *Spiroloculina* is suggested; but the initial part, with its quinqueloculine chamber arrangement, and the rounded margin always reveal the true taxonomic position.



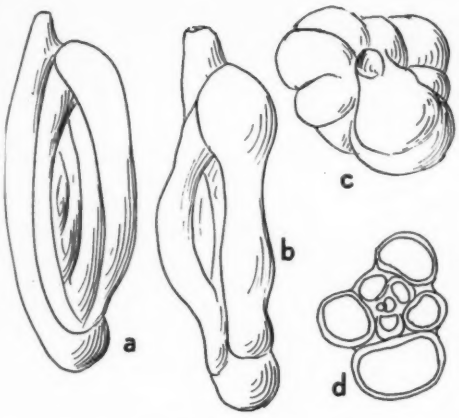
TEXT-FIG. 8—*Sigmoilina tenuis* (Czjzek). (*a,c*) specimen from unit 5a; (*b*) specimen from Unit 11; (*d*) specimen from unit 12; all ×80; (*e,f*) *Spiroloculina jarvisi* Cushman & Todd, specimen from unit 6, ×80.

SIGMOILINA ECUADORENSIS Hofker, n. sp.
Text-fig. 9

This species is much larger than *Sigmoilina tenuis*. It does not show biserially arranged chambers and may be confused with a *Quinqueloculina*. However, the long narrow chambers, the lack of a tooth, and the totally surrounding chamber-walls in transverse section reveal the true status of the genus.

Test elongate, nearly twice as long as broad. Chambers quinqueloculine, long and narrow, last chamber ending in a protruding neck. Transverse section sigmoiline. Length about 0.80 mm., breadth 0.30–0.35 mm.

Type locality.—Sea cliffs at Ancon, southwest Ecuador. Type level: "Clay Pebble" beds, upper Middle Eocene; abundant. Type



TEXT-FIG. 9—*Sigmoilina ecuadorensis*, n. sp. (*a,b,c,*) different views of holotype; (*d*) section of topotype: all ×65.

specimens have been deposited in the Cushman Collection at the U. S. National Museum, P4902 (6 syntypes).

Genus SPIROLOCULINA d'Orbigny, 1826
SPIROLOCULINA JARVISI Cushman & Todd
Text-fig. 8-e,f.

Spiroloculina jarvisi CUSHMAN & TODD, 1944, Cushman Lab. Foram. Res., Spec. Pub. 11, p. 14, pl. 3, fig. 9; CUSHMAN & STAINFORTH, 1951, Jour. Paleont., vol. 25, p. 145, pl. 25, fig. 36.

Several typical specimens of this species were found at localities 5, 6, 7 and 11. The square margin and lack of a quinqueloculine nucleus make it readily separable from *Sigmoilina tenuis*.

Family LAGENIDAE

This family constitutes a large group of Foraminifera distinct from all others. The walls are always hyaline; the pores spread all over the chamber walls are extremely fine; the aperture may be simple, radiate or siphonate, or may consist of a chamberlet partly separated from the main final chamber; in no species of the Lagenidae have real toothplates been found.

The primitive chamber arrangement seems to be a planispiral coil, since this initial form is seen in microspheric, but not in megalospheric, specimens of many elongate species. A trochoidal tendency may appear as an end-stage of evolution (*Darbyella*). In another lineage the tests develop biserially arranged chambers (*Kyphopyxa, Bolivinella, Plectofrondicularia*); these may belong to the *Geinitzina* lineage.

The present classification is unsatisfactory. Many so-called genera seem to be merely generations of other genera. In the single-chambered group known as "*Lagena*" all tests studied have shown a secondarily closed opening at the aboral end. This suggests that these tests are simply loosened end-chambers of other genera, some of which (*e.g.* Pleurostomellidae, Uvigerinidae) may have nothing to do with the Lagenidae. The whole group needs to be re-studied in respect to phylogeny and reproductionary stages.

Genus LENTICULINA Lamarck, 1804

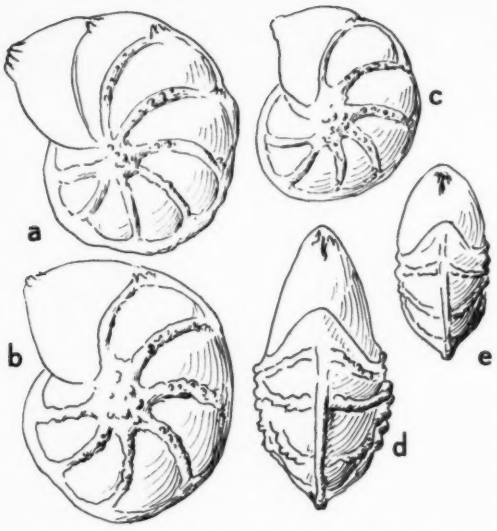
There have been many attempts to separate coiled forms of the Lagenidae into several genera. However, there are so many intermediate stages between these genera that it would be advisable to gather them into a single genus, *Lenticulina*, with several subgenera, as has been done by Bartenstein.

Ornamented species can be distinguished easily. On the other hand smooth species, especially those with no very typical characters of chamber-shape, etc., can only be distinguished with certainty by measuring the angle of the sutures with the periphery. Within any species, this angle remains constant in all generations, whereas the tightness of coiling and the number of chambers in the final whorl vary in the different generations.

LENTICULINA (ROBULUS)
INUSITATA Cushman
Text-fig. 10

Robulus inusitatus CUSHMAN, 1946, Cushman Lab. Foram. Res., Spec. Publ. 16, p. 7, pl. 2, fig. 1–7.

This species, not mentioned by Cushman & Stainforth, is abundant at locality 5. The Ecuador specimens are rather small (up to 0.60 mm.). Uncoiled specimens were not seen in this material, but the angle of the sutures with the periphery is always 80° as in specimens from the Upper Eocene Cocoa sands of Alabama.

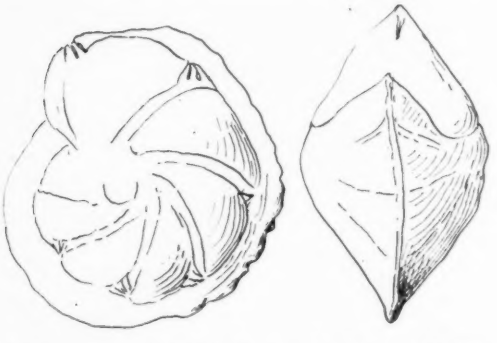


TEXT-FIG. *10—Lenticulina (Robulus) inusitata* Cushman. Specimens from unit 5. All ×65.

LENTICULINA(ROBULUS) LIMBOSA (Reuss)
Text-fig. 11

Robulina limbosa REUSS, 1864, Sitz. Akad. Wiss., Wien, vol. 48, p. 55, pl. 6, fig. 69.
Robulus limbosus CUSHMAN, 1946, Cushman Lab. Foram. Res., Spec. Publ. 16, p. 6, pl. 1, fig. 13.
Robulus cf. *inornatus* CUSHMAN & STAINFORTH [not *Robulina inornata* d'Orbigny], 1951, Jour. Paleont., vol. 25, p. 146.

This species was recorded as *R.* cf. *inornatus* from several localities by Cushman & Stainforth. However, it is identical, notably in the wide keel and the constant angle (70°) of the sutures with the periphery, with *Robulus limbosus* (Reuss) as identified by Cushman in the Cocoa sands. As in the Cocoa sands material, the specimens are smaller than those of the European Eocene, ranging up to 0.65 mm. in diameter. It is most common at locality 12.

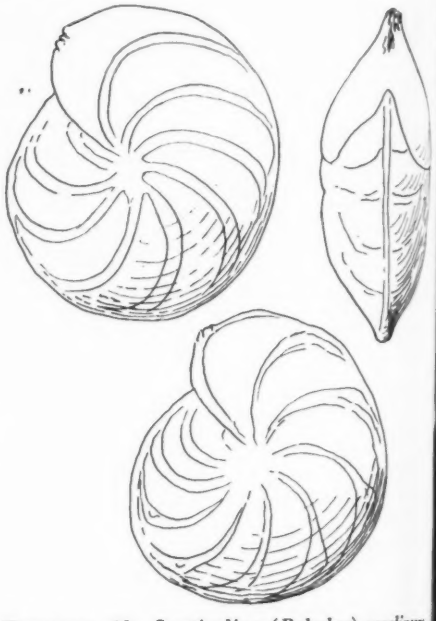


TEXT-FIG. *11—Lenticulina (Robulus) limbosa* (Reuss). Specimen from unit 12, ×65.

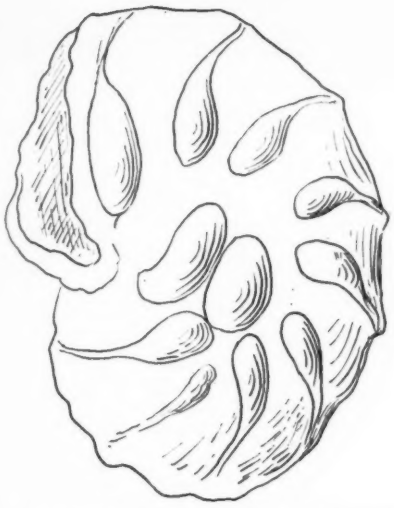
LENTICULINA (ROBULUS) CAROLINEANA Cushman
Text-fig. 12

Robulus arcuato-striatus (Hantken) var. *carolineanus* CUSHMAN, 1933, Cushman Lab. Foram. Res., Contr., vol. 9, pl. 4, pl. 1, fig. 9; CUSHMAN, 1946, ibid., Spec. Publ. 16, p. 10, pl. 1, fig. 14.

This species, not mentioned by Cushman and Stainforth, is common at locality 6. Cushman has described it as widely distributed in the Upper Eocene of America, and his specimens from the Cocoa sands of Alabama are identical with those of Ecuador. The very hyaline test, the strongly curved chambers, the strongly involute coiling and very small free umbilical area, the very slightly keeled or rather acute margin, and the angle of 50° between sutures and periphery are all characteristic features. The sutures are distinct but flush with the surface. Diameter up to 0.66 mm., thickness 0.33 mm.



TEXT-FIG. *12—Lenticulina (Robulus) carolinea* Cushman. Specimens from unit 6, ×65.



TEXT-FIG. *13*—*Lenticulina* (*Robulus*) *gutticostata* (Gümbel). Somewhat damaged specimen from locality 4, ×40.

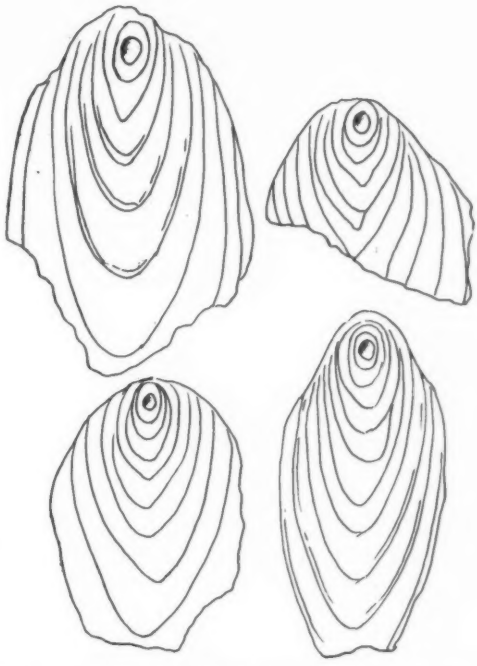
LENTICULINA (ROBULUS) GUTTICOSTATA (Gümbel)
Text-fig. 13

Robulina gutticostata GÜMBEL, 1868, K. Bayr. Akad. Wiss., kl. 2, vol. 10, p. 643, pl. 1, fig. 74.
Robulus gutticostatus CUSHMAN, 1935, U. S. Geol. Surv., Prof. Pap. 181, p. 15, pl. 5, fig. 1,2; CUSHMAN & CEDERSTROM, 1945, Virginia Geol. Surv., Bull. 67, p. 10, pl. 1, fig. 4,5.
(?) *Robulus cocoaensis* CUSHMAN, Cushman Lab. Foram. Res., Spec. Publ. 16, p. 6, pl. 1, fig. 15,16.

A single specimen of this well-known Eocene species was found at locality 4. The guttiform thickening of the sutures is typical. The validity of *R. cocoaensis* as a separate species is considered doubtful.

Genus FRONDICULARIA Defrance, 1824
FRONDICULARIA SUBHUNTERI Hofker, n. sp.
Text-fig. 14

Test very thin, leaf-like, rather elongate, nearly twice as long as broad, with a rounded proloculus always completely surrounded by the next chamber and in some cases also by the third one. The later chambers embrace the earlier portion but do not surround the proloculus. Sutures thin and almost flush with the surface, or slightly raised. Angle of the sutures at the axis about 70°. Wall thin and yellowish or hyaline. Length about 0.80 mm., breadth 0.36–0.50 mm.



TEXT-FIG. *14*—*Frondicularia subhunteri*, n. sp. Cotypes from locality 5a, ×65.

This species is very much like *Frondicularia hunteri* Bermudez from the Oligocene of Dominica, B.W.I., but differs in the fewer chambers surrounding the proloculus and in the somewhat more elongate shape of the test. It may only be a subspecies of *F. hunteri*.

Type locality.—Sea cliffs at Punta Mambra, southwest Ecuador. Type level: Seca formation, Upper Eocene; plentiful. Type specimens have been deposited in the Cushman Collection, U. S. National Museum, P4904 (7 syntypes).

Genus STILOSTOMELLA Guppy, 1894
(and similar forms)

The Upper Eocene of Ecuador and Peru contains several nodosarian species to which the name *Ellipsonodosaria* has usually been applied. However, *Ellipsonodosaria* is now considered an invalid synonym of *Nodosarella* (Finlay 1947, Stainforth 1952). The specimens under consideration are certainly not nodosarellas, being different in their apertures and wall structure. The genus *Stilostomella* Guppy, 1894 [=*Siphonodosaria*

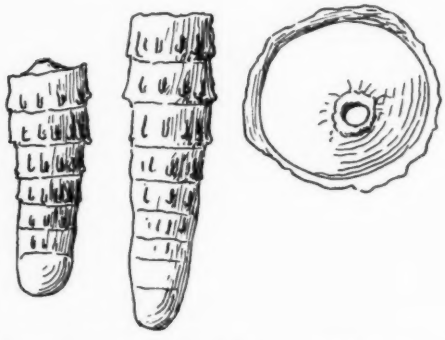
Silvestri, 1924, and authors] seems the most appropriate place to group these species. Two of the Ecuador species show an apertural tooth as is present in the type species of *Stilostomella*. Two other species do not possess this important feature. Possibly the group is polyphyletic, with the Ellipsoidisidae, Uvigerinidae and Lagenidae as ancestral families to the homeomorphic lineages.

STILOSTOMELLA (?) COSTATA
Hofker, n. sp.
Text-fig. 15

Ellipsonodosaria sp. *A* CUSHMAN & STONE, 1947, Cushman Lab. Foram. Res., Spec. Pub. 20, p. 19, pl. 2, fig. 29.
Ellipsonodosaria curvatura CUSHMAN & STAINFORTH, 1951 [pars], Jour. Paleont., vol. 25, p. 156, pl. 26, fig. 66.

Test elongate, consisting of a row of very slightly tapering chambers with straight sutures, not depressed; chambers strongly overlapping. Wall of each chamber ornamented with short costae, which are most prominent toward the initial end and do not fuse together along the test. Transverse section circular. Septal foramina central, circular, with no indication of toothplates. Aperture terminal with rimmed border, circular. Test transparent, yellowish, with very fine pores all over except on the costae. Length up to 0.60 mm., terminal diameter 0.15 mm. Common in Unit 5.

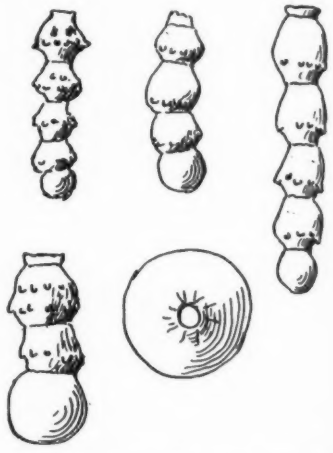
Type locality.—Between the two main tributaries of Rio Jusá, 14 to 15 km. ESE of Colonche, southwest Ecuador. Type level: Jusá formation, Upper Eocene. [Editorial note: Types were to have been deposited in the U. S. National Museum. Loeblich states that there are no specimens so labelled.]



TEXT-FIG. *15*—*Stilostomella* (?) *costata*, n. sp. Side views of cotypes, ×80, and view of rounded, toothless aperture, ×235.

STILOSTOMELLA (?) CURVATURA
(Cushman)
Text-fig. 16

Ellipsonodosaria curvatura CUSHMAN, 1939, Cushman Lab. Foram. Res., Contr., vol. 15, p. 71, pl. 12, fig. 6; CUSHMAN & STONE, 1947, ibid., Spec. Pub. 20, p. 18, pl. 2, fig. 28; CUSHMAN & STAINFORTH, 1951 [pars], Jour. Paleont., vol. 25, p. 156.



TEXT-FIG. *16*—*Stilostomella* (?) *curvatura* (Cushman). Specimens from locality 5, side views, ×80, and view of rounded, toothless aperture, ×235.

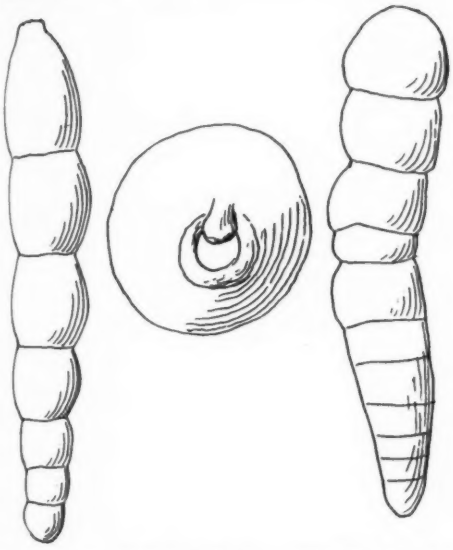
This species is typified by its globular chambers and highly depressed sutures, with one or two rows of short dentiform spines at or near the base of each chamber. The aperture and septal foramina are circular with no indication of toothplates. Abundant at locality five.

STILOSTOMELLA VERNEUILI (d'Orbigny)
Text-fig. 17

Dentalina verneuili D'ORBIGNY, 1846, Foram. foss. du bass. tert. de Vienne, p. 48, pl. 2, fig. 7,8.
Ellipsonodosaria sp. CUSHMAN, 1946, Cushman Lab. Foram. Res., Spec. Publ. 16, p. 30, pl. 6, fig. 9
Ellipsonodosaria verneuili CUSHMAN & STAINFORTH, 1951, Jour. Paleont., vol. 25, p. 156, pl. 27, fig. 3,4.

A smooth form with an initial chamber usually carrying a short excentric spine, followed by a set of short chambers, gradually

lengthening until about 1½ times as long as broad. Sutures slightly depressed, later chambers slightly inflated. Aperture and septal foramina half-moon shaped, each with a blunt tooth. The orientation of the apertural tooth is reversed in successive chambers, indicating a spiral mode of growth with rotation of 180° between chambers. Abundant at locality 5.



TEXT-FIG. *17—Stilostomella verneuili* (d'Orbigny). Two tests from locality 6, side views, ×80, and end view showing the tooth over the aperture, ×235.

STILOSTOMELLA COCOAENSIS (Cushman)
Text-fig. 18

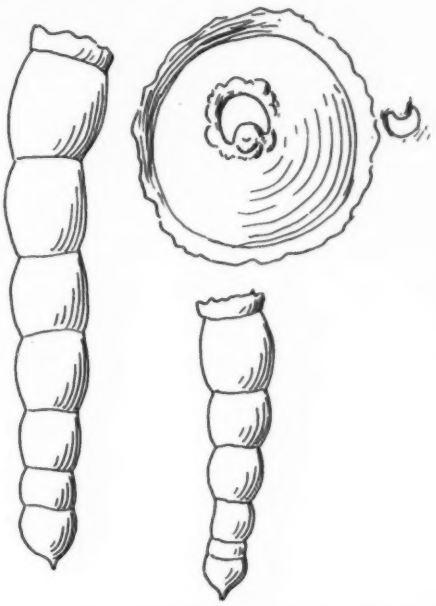
Nodosaria cocoaensis CUSHMAN, 1925, Cushman Lab. Foram Res. Contr., vol. 1, p. 66, pl. 10, fig. 5,6.

Ellipsonodosaria cocoaensis CUSHMAN, 1939, ibid., Contr., vol. 15, p. 68, pl. 11, fig. 27–33; ——, 1946, ibid., Spec. Publ. 16, p. 30, pl. 6, fig. 10.

Ellipsonodosaria sp. B CUSHMAN & STONE, 1947, ibid., Spec. Publ. 20, p. 19, pl. 2, fig. 30.

(?) *Dentalina*? cf. *mucronata* CUSHMAN & STAINFORTH, 1951, Jour. Paleont., vol. 25, p. 147, pl. 26, fig. 4.

A smooth form with bluntly rounded initial end and very short chambers, much shorter than those of *S. verneuili*. Final chamber pyriform, slightly longer than broad. Test usually curved or bent. Aperture and septal foramina as in *S. verneuili*. Abundant at locality 5.



TEXT-FIG. *18—Stilostomella cocoaensis* (Cushman). Specimens from locality 5; side views ×80, apertural view ×235; the aperture of the preceding chamber is sketched at the side to show the alternating position of the tooth.

Genus PLECTOFRONDICULARIA Liebus, 1903
Text-fig. 19,20

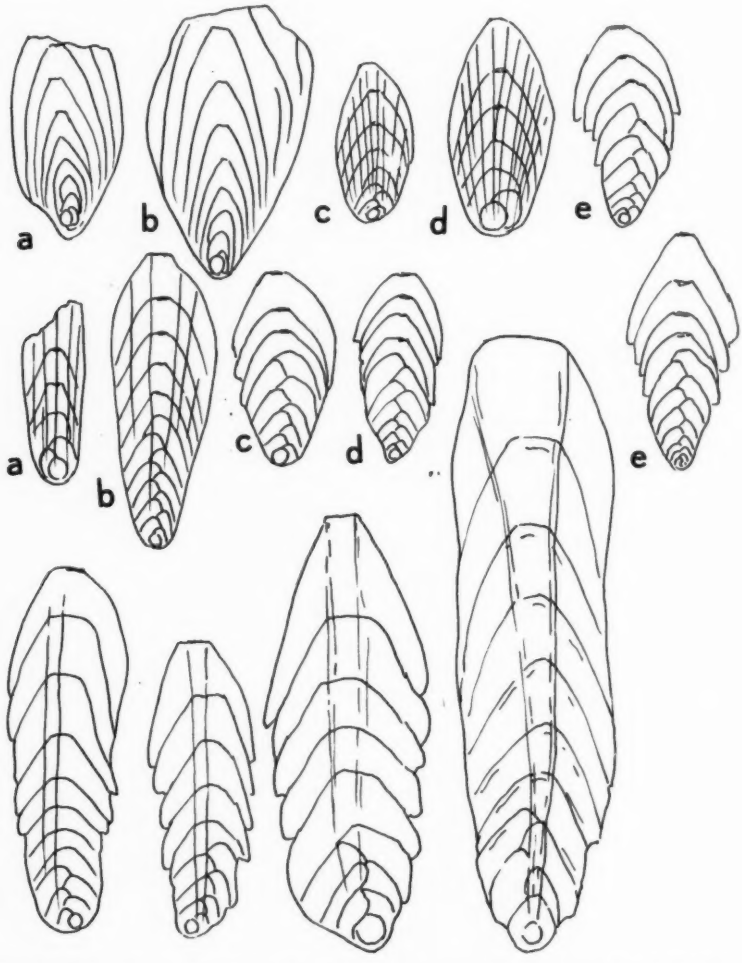
Cushman placed this genus in his family Heterohelicidae and described it as follows (1948, p. 258): "Test elongate, compressed, microspheric form planispiral, then biserial, then uniserial, rectilinear, much compressed; wall calcareous, finely perforate; aperture in adult terminal, elliptical."

Examination of hundreds of tests in our material showed no planispiral initial parts. Microspheric specimens start biserially (proloculus diameter 10–12μ). However, in megalospheric tests, especially in younger Tertiary and Recent species, the number of oblique biserial chambers may be reduced to one. In such specimens the succession of large proloculus, oblique "biserial" chamber, and first arcuate chamber of the uniserial portion may look misleadingly like a short planispiral coil; this may explain Cushman's diagnosis.

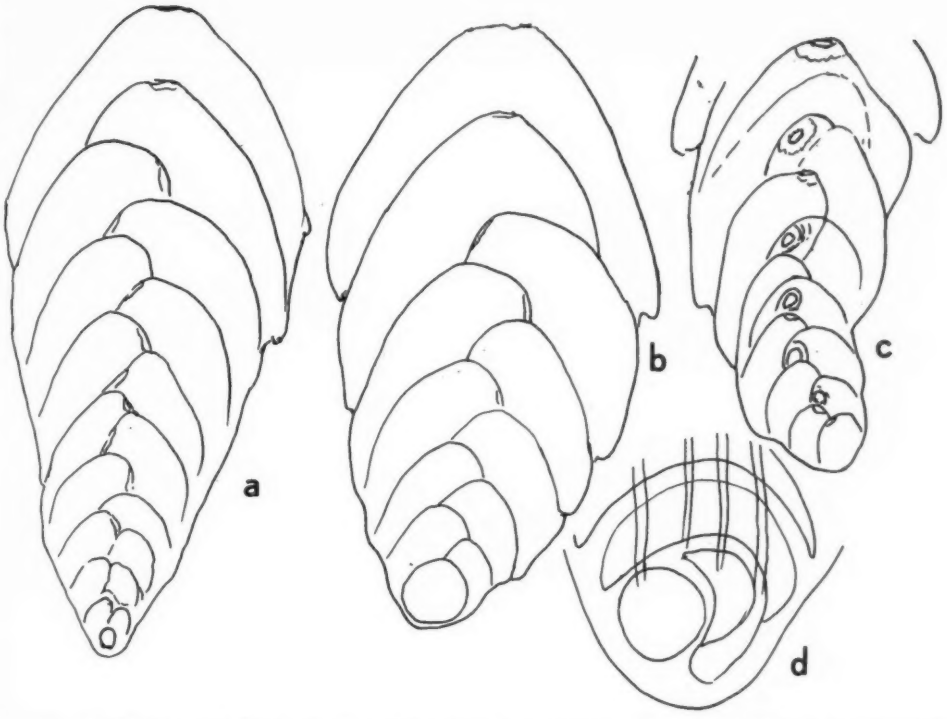
The genus shows all the characters of true lagenid tests: the walls are radiate; the aperture is a simple rounded or slightly

elongate opening; no toothplates are formed; the pores are the very fine pores of all Lagenidae. There seem to be three groups of Lagenidae which start biserially: *Kyphopyxa* from the uppermost Cretaceous, *Plectofrondicularia* from Eocene to Recent, and *Bolivinella* from Eocene to Recent. All three genera show nearly the same characters, namely a rounded aperture, biserial arrangement of chambers, at least in their early stages, very fine pores and radiate walls. Hence *Bolivinella* and *Plectofrondicularia* appear to be derived from *Kyphopyxa*.

In the material from the Eocene of Ecuador five species of *Plectofrondicularia* have been found. Two of them are without any ornamentation; these are *P. vaughani* from locality 6 and *P. dentifera* from locality 5. A third species is always very elongate and narrow, with two costae along the axis, and usually distinctly dentate along the margin; this is *P. peruviana*, not recorded by Cushman & Stainforth but abundant at locality 5a. An elongate form with four or five costae seems identical with *P. cookei*, and a very broad form with numerous costae is *P.*



TEXT-FIG. *19*—*Plectofrondicularia* spp., all ×80. Upper row: (*a,b*) *P. vaughani* Cushman from unit 6; (*c,d*) *P. packardi* Cushman & Schenck var. *multilineata* Cushman & Simonson from unit 5; (*e*) *P. dentifera* Cushman & Stainforth from unit 5. Middle row: (*a,b*) *P. cookei* Cushman from unit 5; (*c,d,e*) *P. dentifera* from unit 5. Lower row; *P. peruviana* Cushman & Stone from locality 5a.



TEXT-FIG. 20—*Plectofrondicularia dentifera* Cushman & Stainforth. (*a*) microspheric and (*b*) megalospheric form; (*c*) side view showing the rounded, collared apertures. *Plectofrondicularia cookei* Cushman. (*d*) initial part of megalospheric individual, showing second chamber at side of proloculus. All ×235.

packardi var. *multilineata*. Both costate forms are common at locality 5.

These species encountered in the Eocene of Ecuador are as follows:

Plectofrondicularia vaughani CUSHMAN, 1927, Cushman Lab. Foram. Res. Contr. vol. 3, p. 112, pl. 23, fig. 3; CUSHMAN & STAINFORTH, 1951, Jour. Paleont., vol. 25, p. 150, pl. 26, fig. 27.

Plectofrondicularia dentifera CUSHMAN & STAINFORTH, 1947, Cushman Lab. Foram. Res. Contr. vol. 3, p. 77, pl. 7, fig. 2,3; 1951; Jour. Paleont., vol. 25, p. 150, pl. 26, fig. 28,29.

Plectofrondicularia peruviana CUSHMAN & STONE, 1947, Cushman Lab. Foram. Res. Spec. Publ. 20, p. 11, pl. 1, fig. 1–3.

Plectofrondicularia cookei CUSHMAN, 1933, ibid., Contr., vol. 9, p. 11, pl. 1, fig. 26; CUSHMAN & STAINFORTH, 1951, Jour. Paleont., vol. 25, p. 150, pl. 26, fig. 25.

Plectofrondicularia packardi var. *multilineata* CUSHMAN & SIMONSON, 1944, ibid., vol. 18, p. 197, pl. 32, fig. 2–4; CUSHMAN & STONE, 1947, Cushman Lab. Foram. Res. Spec. Publ. 20, p. 11, pl. 2, fig. 5; CUSHMAN & STAINFORTH, 1951, Jour. Paleont., p. 150, pl. 26, fig. 26.

Statistical study of the Ecuadorean plectofrondicularias show an inverse relationship between the number of biserial chambers and the size of the proloculus. In *P. dentifera* proloculi of 12–14μ are followed by 13–17 biserial chambers; proloculi of 20–22μ by about 12 chambers, those of 26–28μ by only nine or ten chambers. In *P. peruviana* the proloculus is much larger than in *P. dentifera*, measuring from 28 to 42μ, but a similar relationship is seen. Tests with proloculus diameter of 40μ show only a couple of biserial chambers, but those with a proloculus of 30μ show six biserial chambers. Species in the younger Tertiary develop very large proloculi and usually lack the biserial development completely. Hence it seems that in the whole genus, not merely in individual species, we may expect the length of the biserial portion to vary inversely with the size of the proloculus. In *P. dentifera* the average proloculus diameter is 20μ and the

average number of biserial chambers is 13: in *P. peruviana* the average proloculus size is 32μ and the average number of biserial chambers is six.

Family GLOBOBULIMINIDAE, new family

In his work on the Dentata, the author restricted the genus *Virgulina* to species with hyaline walls and more or less complicated toothplates (Hofker, 1951, p. 237). In the same work (p. 264) he introduced a new generic name, *Cassidella*, for species more or less identical but having opaque test-walls and simple toothplates as in the Cassidulinidae. Later study in polarized light showed a wide difference between the two genera, the hyaline species having radiate shell structure, the opaque forms having granular structure as in the Cassidulinidae (Micropaleontologist, vol. 7, pt. 4, p. 27, 1953). However, since the genotype of *Virgulina* is *V. squammosa* d'Orbigny, which proved to belong to the opaque forms (1951, p. 268–271), *Cassidella* becomes a synonym of *Virgulina*.

Hence the group of species with opaque tests, undoubtedly belonging to the Cassidulinidae, must be called *Virgulina* and removed from the Buliminidae of Cushman. Moreover a new generic name, *Stainforthia*, is introduced for the hyaline group of species.

In the Siboga report (Hofker, 1950) the family Virgulinidae was recognized, consisting of *Stainforthia* ("*Virgulina*"), *Protoglobobulimina*, *Praeglobobulimina* and *Globobulimina*. But with removal of *Virgulina* to the Cassidulinidae a new family-name Globobuliminidae becomes necessary, here proposed and defined as follows: The Globobuliminidae include genera in which the test walls are always very hyaline and mostly thin; the arrangement of the chambers is at first triserial, at least in the initial part of the microspheric form, but later, and sometimes in the whole test, it is biserial; the tests often show a twisted habitus, and the earlier chambers are usually overlapped strongly by the later ones; the apertures are always loop-shaped and sutural, or in highly advanced forms terminal (*Globobulimina*); the aperture always has a toothplate, in *Stainforthia* showing a free folded part which is often serrated, in highly advanced forms this part becomes somewhat fan-shaped and protrudes from the aperture; pores in *Stainforthia* and *Praeglobobulimina* fine and circular, but in *Protoglobobulimina* and *Globobulimina* elongate.

Genus STAINFORTHIA, Hofker, n. gen.

Synonymy: *Virgulina* auct. (non d'Orbigny, 1826)

Genotype: *Virgulina concava* Höglund, 1947, Uppsala Univ., Zool. Bidrag, Bd. 26, p. 257, pl. 23, fig. 3,4; pl. 32, fig. 4–7; Text-fig. 273–275.

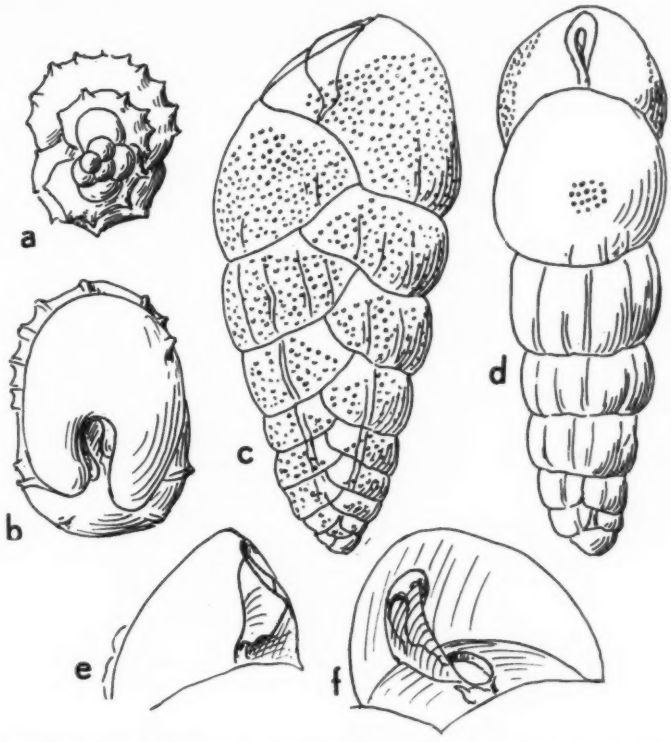
Description.—In many species triserial in the initial part, at least in the microspheric form, then becoming biserial, in most forms somewhat twisted. In advanced forms the triserial part may be suppressed, the test being biserial throughout. Chambers always inflated, overlapping former chambers at the sides of the test. Walls very hyaline, thin, with very fine but distinct pores, smooth or ornamented. Aperture always loop-shaped with a toothplate; border of the free folded part of the toothplate in most cases dentate or serrated. The plait-like appearance and the often twisted arrangement of the chambers are typical. Often a spine is present at the initial end. The genus is named after R. M. Stainforth.

STAINFORTHIA DALLIFORMIS Hofker, n. sp.
Text-fig. 21

Loxostomum dalli CUSHMAN & STAINFORTH, 1951 [not Cushman, 1946], Jour. Paleont., vol. 25, p. 155, pl. 26, fig. 58.

When examining Eocene Cocoa sands Foraminifera from Alabama, the author analyzed *Loxostomum dalli* (Cushman) and concluded that that species is a *Bolivina*. Specimens very much like those from the Cocoa sands are common at locality 5 in Ecuador and were given the same name by Cushman & Stainforth. Yet they differ, since the toothplate is different and the first chambers in the microspheric form are triserially arranged. So the species found in the Eocene of Ecuador is neither a *Bolivina* nor a *Loxostomum*, but *Stainforthia*.

The small test is very hyaline, oval in transverse section. In the microspheric form two sets of triserially arranged chambers are



TEXT-FIG. 21—*Stainforthia dalliformis*, n. sp. (*a*) microspheric initial part; (*b*) apertural face; (*c,d*) side views; (*e*) last formed chamber, showing toothplate; (*f*) view inside last formed chamber, showing previous aperture and the adhering toothplate running between apertures. *a–e*, ×235; *f*, ×300.

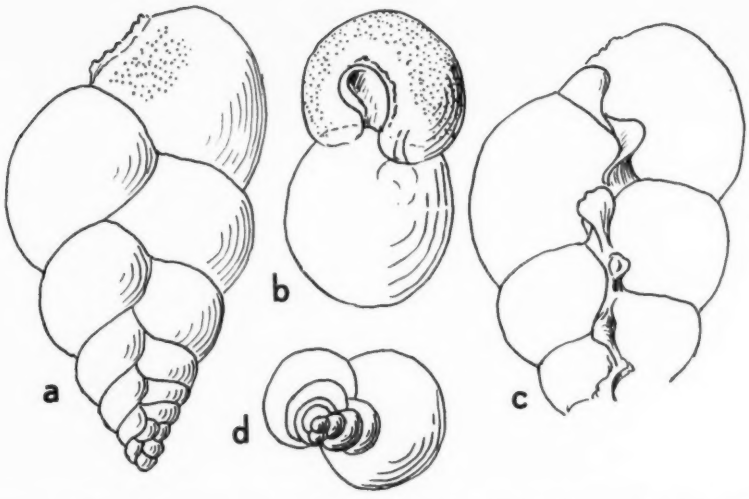
followed by about seven pairs of biserial chambers. The chambers are strongly overlapping. The pores in the walls are fine but very distinct, present only near the proximal sutures, so that on all chambers a triangular patch, distally placed at the axis of the test, is poreless. The apertural face is also poreless. In it a loop-shaped aperture is found at the suture of the final chamber. The simple toothplate is attached at the basal chamber-wall, runs from one border of the final septal foramen towards the borders of the previous one, and forms a broad free folded part which is crenulated at its border. The whole early test and the bases of the last formed chambers are covered by fine longitudinal ridges.

The species differs from *Bolivina* ("*Loxostomum*") *dalli* in the triserial arrangement of the first chambers in the microspheric form, in the crenulated border of the toothplate, and in the slightly more slender test. It seems to be a new species, though possibly closely related to *B. dalli* (Cushman). It may be that the age of the Cocoa sand is somewhat younger than the Ecuador unit 5 (Seca formation), and that *Stainforthia dalliformis* evolved into *Bolvina dalli* by losing its triserial part.

Type locality.—Shale outcrops between the two main tributaries of Rio Jusá, 14 km. to 15 km. ESE of Colonche, southwest Ecuador. Type level: Jusá formation, Upper Eocene. Type specimens have been deposited in the Cushman Collection, U. S. National Museum, P4905.

STAINFORTHIA VENEZUELANA (Nuttall)
Text-fig. 22

Gümbelina venezuelana NUTTALL, 1935. CUSHMAN & STONE, 1947, Cushman Lab. Foram. Res., Spec. Pub. 20, p. 10, pl. 1, fig. 28; CUSHMAN & STAINFORTH, 1951, Jour. Paleont., vol. 25, p. 149, pl. 26, fig. 23.



TEXT-FIG. 22—*Stainforthia venezuelana* (Nuttall). (*a*) side view; (*b*) apertural view; (*c*) longitudinal section showing toothplates; (*d*) initial chambers. All ×235, from locality 5.

This species was found at locality 5. The proloculus is very small, and is followed by a set of three chambers forming the first whorl; then five pairs of inflated chambers follow in biserial arrangement. The depressed sutures are curved and run slightly backwards. The walls are very hyaline and pierced by very fine pores. Around the aperture on the last formed chamber is a poreless area. The aperture is not, as in all species of *Gümbelina*, a wide rounded opening, but is loop-shaped, distinctly bent to one side of the chamber, reaching the suture. It is surrounded by a slightly protruding border. In a clarifier, each foramen shows a well developed toothplate, running near the axis of the test from one septal foramen to the next one, in such a way that a free folded part is formed, slightly protruding in each foramen, with a smooth or slightly dentate border. Each new toothplate begins at the part of the foramen where the previous toothplate is attached.

Toothplates do not occur in *Gümbelina*, and other characteristics point to quite a different genus. The triserial arrangement of the first formed chambers, together with the very hyaline walls and the shape of the toothplate, are typical features of the genus *Stainforthia*, as defined above. It is very remarkable that in the Oligocene some species of "*Bolivina*" occur, only differing from *Stainforthia venezuelana* in having lost the initial triserial stage.

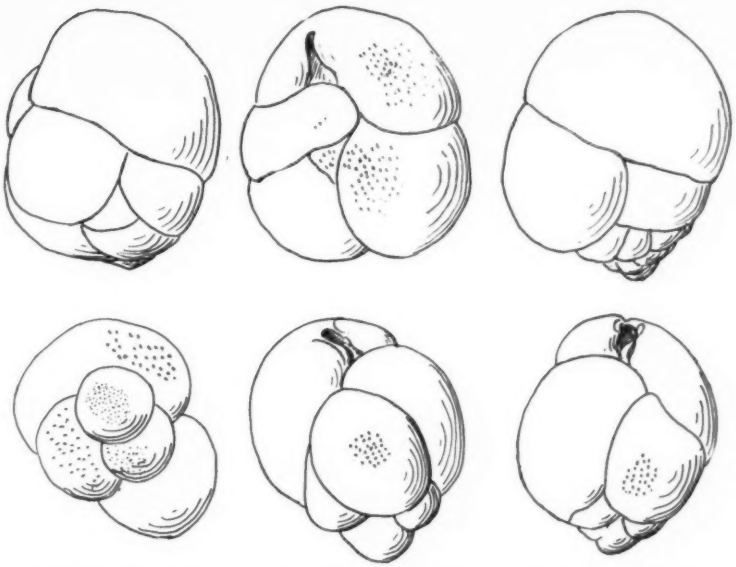
Genus PROTOGLOBOBULIMINA Hofker, 1951

PROTOGLOBOBULIMINA DECURTATA (Cushman & Stainforth)

Text-fig. 23,24

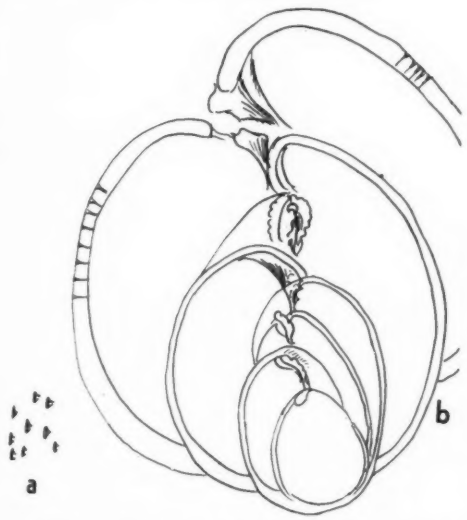
Bulimina decurtata CUSHMAN & STAINFORTH, 1947, Cushman Lab. Foram. Res. Contr., vol. 23, p. 80, pl. 17, fig. 11; 1951, Jour. Paleont., vol. 25, p. 153, pl. 26, fig. 47.

The external characters of this species are well described by Cushman & Stainforth. The initial face shows triserially arranged chambers, but in the later stages the growth tends to become biserial. The first two chambers show very fine protopores, whereas the later chambers have somewhat larger and wider set pores. Pore-index (explained under Globigerinidae) of the first two chambers is 34—0.1×500; of the later chambers 14—0.5 ×500. Longitudinal sections show that the megalospheric initial chamber is pyriform, as in *Globobulimina;* the walls are thin, especially those of the earlier whorls. The toothplate is of the primitive type with a narrow free folded part, the border of which is slightly dentate. Around the aperture an inconspicuous but distinct collar is formed. All these characters do not point to *Bulimina* but to *Globobulimina;* moreover the chambers are highly involute. Yet the pores in



TEXT-FIG. *23—Protoglobobulimina decurtata* (Cushman & Stainforth). Various aspects of specimens from locality 6, showing chamber arrangement and the elongate pores, all ×65; (*a*) initial chambers, ×240.

younger specimens are rounded, and not elongate as in Recent species of *Globobulimina;* but in mature specimens the later chambers have distinctly elongate pores as in *Globobulimina*. We have here a link between *Stainforthia* or *Bulimina* and *Globobulimina*. Hence the species is best referred to the genus *Protoglobobulimina*.



TEXT-FIG. *24—Protoglobobulimina decurtata* (Cushman & Stainforth). (*a*) pores, ×240; (*b*) longitudinal section, indicating pores in the wall and toothplates in the axis, ×180.

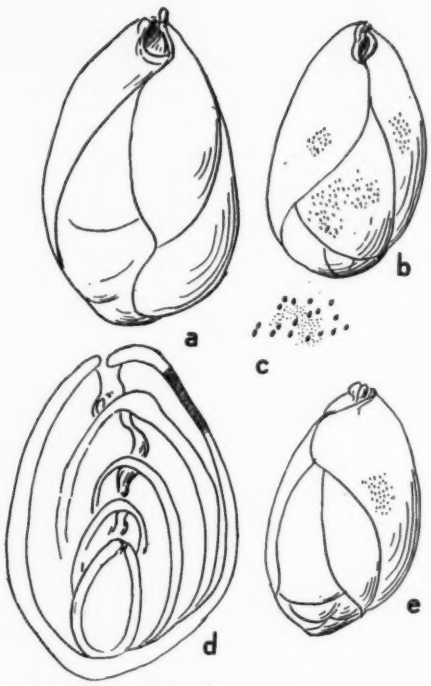
Genus GLOBOBULIMINA Cushman, 1927 (emend. Höglund, 1947)

GLOBOBULIMINA OREGONENSIS Cushman & Stewart

Text-fig. 25

Globobulimina pacifica Cushman var. *oregonensis* CUSHMAN & STEWART, 1947, Oregon, Dept. Geol. Min. Industries, Bull., no. 36, pt. 5, p. 101, pl. 12, fig. 13; ibid, pt. 3, p. 61, pl. 8, fig. 6; ibid, pt. 4, p. 78, pl. 11, fig. 4.

Test oval in shape, somewhat tapering towards the apertural end, broadest at about one-third from the initial end. Transverse section rounded. Last-formed chamber nearly surrounding the test except for a small part at the initial end and a triangular opening at the side, in which the aperture is visible. Below the aperture the two wings of the final chamber fuse, forming a more or less distinct suture (as in "*Desinobulimina*"). Aperture a narrow loop-shaped slit at the end of the test, surrounded by a slightly developed collar, with a slightly protruding pillar-shaped toothplate. Walls in section thick for the genus, pierced by two kinds of pores, very fine ones visible only in trans-



TEXT-FIG. *25*—*Globobulimina oregonensis* Cushman & Stewart. Specimens from locality 10. (*a,b,e*) external views, ×65; (*c*) surface of the test showing the two kinds of pores, very fine ones and larger elongate ones, ×240; (*d*) longitudinal section, showing some pores and the pillar-like toothplates, ×65.

verse section or with high magnification, and larger ones which are circular in shape, and not elongate. The larger pores are of the type of *Stainforthia* and not yet that of real *Globobulimina*. The pillar-shaped toothplate, however, indicates true *Globobulimina*.

Length 0.50–0.70 mm.; breadth 0.30–0.42 mm.

Common at locality 10 and also found at locality 8. Its original record is from the Upper Eocene of Oregon.

Family BOLIVINIDAE
Genus BOLIVINA d'Orbigny, 1839

Test from the beginning biserial, in reality trochoid with a high rate of coiling, two chambers in a whorl. Wall always hyaline or slightly opaque. Pores always protopores, fine to distinct; part of the wall of each chamber often poreless, especially near to the aperture, either distinctly ornamented or totally smooth. Aperture loop-shaped, sutural, but in some cases closed at the sutural part and then appearing terminal, though actually the closing-suture is always visible. (These forms have frequently been determined as *Loxostomum* Ehrenberg, but they are found as the end-stages of quite different lineages and cannot properly be grouped as a single genus: moreover, the true *Loxostomum* Ehrenberg, 1854, is a genus with no toothplate, now usually known as *Bolivinitella* Marie, belonging to a different family.)

An end-stage in the development of some forms seems to have appeared in the Upper Cretaceous or Lower Tertiary. This genus forms a spiral stage in the beginning of the test, but in all other respects shows the bolivine structure throughout. It is described later in this paper as *Spirobolivina*, n. gen.

A large group of bolivine species shows part of each chamber overlapping the previous chamber at the axis and sometimes at other points along the suture. These species have been gathered in a separate genus, *Bolivinoides* Cushman, 1927, though in all other characters they are normal Bolivinas. They always show a very simple but distinct toothplate. The chambers are always bent backward near to the margin and the transverse section is rhomboid. Such species may be regarded as a subgenus of *Bolivina*, ranging from Upper Cretaceous to Recent.

BOLIVINA CARINATA Terquem
Text-fig. 26

Bolivina carinata TERQUEM, 1882, Soc. Géol. France, Mém., sér. 3, tome 2, no. 3, p. 148, pl. 15, fig. 19. CUSHMAN, 1937, Cushman Lab. Foram. Res., Spec. Publ. 9, p. 46, pl. 6, fig. 14–16.

This species from the Eocene of the Paris Basin does not differ from several specimens found at locality 12 in the Eocene of Ecua-

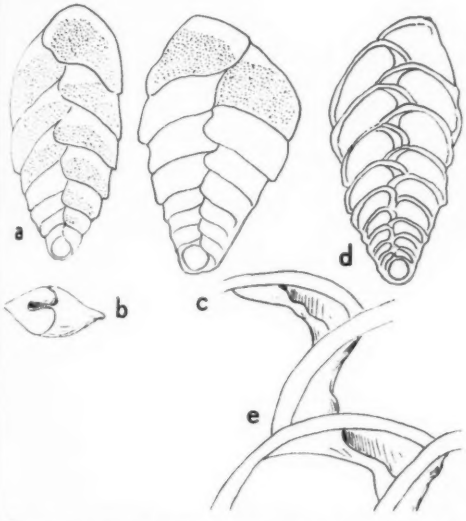
TEXT-FIG. *26*—*Bolivina carinata* Terquem. Specimens from unit 12. Two external views, ×655, and a terminal view, showing the toothplates, ×180.

dor. Topotypes have been compared. The test is subtriangular with an acute or slightly rounded initial angle. The periphery is smooth in contour, acute in cross section. The chambers are narrow and the sutures strongly bent backwards. Each suture shows a thickened part near the axis of the test, and there are no pores on these portions. On the rest of the test the pores are numerous and distinct, though fine. The toothplate shows a broad attached part and a strongly developed free folded part with a slightly lobulated border, which protrudes slightly in the narrow slit-like aperture. The test is always very hyaline. Length of test in the Ecuador material, 0.40 mm., breadth 0.24 mm.

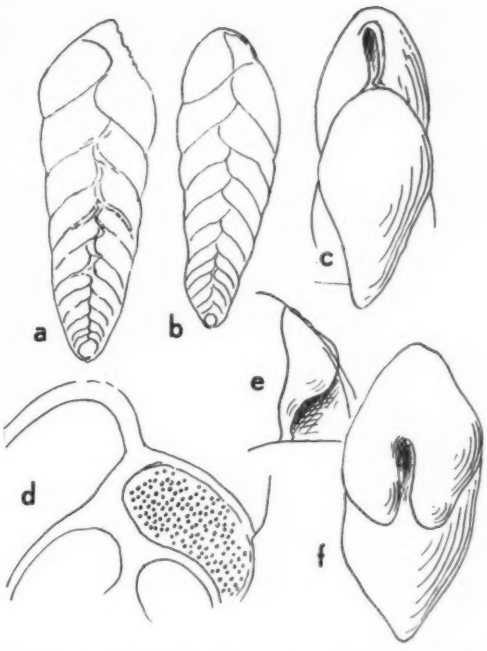
BOLIVINA BASISENTA
Cushman & Stone
Text-fig. 27

Bolivina basisenta CUSHMAN & STONE, 1947, Cushman Lab. Foram. Res., Spec. Publ. 20, p. 15, pl. 2, fig. 20.

The acute periphery, rhombiform transverse section, long narrow aperture, and broad test, together with the denticulated margins, make this a distinctive species. The pores are very fine and a triangular space



TEXT-FIG. *27—Bolivina basisenta* Cushman & Stone. Specimens from locality 5a. (*a,c*) external views, with distribution of pores shown on some chambers, ×65. (*b*) apertural view, ×65; (*d*) longitudinal section, showing toothplates, ×65; (*e*) enlarged view of toothplates, ×180.



TEXT-FIG. *28—Bolivina jacksonensis* Cushman & Applin. Specimens from locality 5a. (*a,b*) external views, ×65; (*c*) apertural view, ×180; (*d*) portion of test showing distribution of pores, ×180; (*e*) toothplate, ×240; (*f*) apertural view, ×180.

near the upper axial part of each chamber is poreless. The toothplate is very conspicuous, since its attached part runs boldly backward along the border of the long aperture, while the free folded part is narrow.

The species was found abundantly at locality 5a.

BOLIVINA JACKSONENESIS
Cushman & Applin
Text-fig. 28

Bolivina jacksonensis CUSHMAN & APPLIN, 1926, Amer. Ass. Petr. Geol. Bull., vol. 10, p. 167, pl. 7, fig. 3,4; CUSHMAN & STONE, 1947, Cushman Lab. Foram. Res. Spec. Publ. 20, p. 15, pl. 2, fig. 19; CUSHMAN & STAINFORTH, 1951, Jour. Paleont., vol. 25, p. 155, pl. 26, fig. 55,56.

This slender species with its numerous narrow chambers and strongly oblique sutures shows fine but very distinct pores all over the chamber-walls. At the axis of the test the sutures are thickened. The transverse section is rhomboidal with a fairly acute margin. The aperture is long and narrow, and slightly thickened at one of its bor-

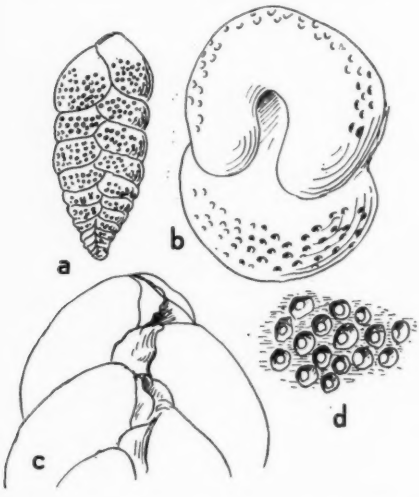
ders by a broad attached part of the toothplate. This plate is slightly curved externally; the free folded part is only broadened at its end.

The species is abundant at localities 5 and 7.

BOLIVINA MACULATA Cushman & Stone Text-fig. 29

Bolivina maculata CUSHMAN & STONE, 1947, Cushman Lab. Foram. Res. Spec. Publ. 20, p. 17, pl. 2, fig. 21; CUSHMAN & STAINFORTH, 1951, Jour. Paleont., vol. 25, p. 155, pl. 26, fig. 54.

This species is common in many of the Ecuador Eocene samples. Some points may



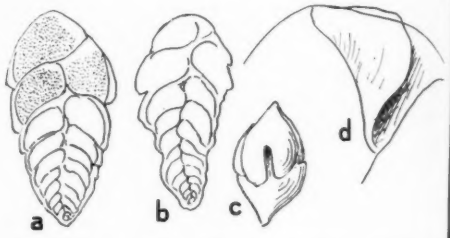
TEXT-FIG. *29—Bolivina maculata* Cushman & Stone. Specimens from locality 5a. (*a*) external view, ×65; (*b*) apertural view, ×180; (*c*) section through last formed chambers, showing toothplates ×180; (*d*) surface of the wall, showing the pores in funnel-shaped pits, ×240.

be added to its earlier descriptions. The pores are not actually very large, but they open into funnel-shaped pits in the wall, thus causing the "peculiar spotted or granular appearance of the surface." The toothplates are relatively large and broad, with a broad attached part and a flaring free folded part, the border of which is slightly lobulate. At the attached part the toothplate protrudes slightly into the next chamber or into the open aperture of the final chamber.

BOLIVINA MEXICANA Cushman Text-fig. 30

Bolivina mexicana CUSHMAN, 1926, Cushman Lab. Foram. Res., Contr., vol. 1, p. 81, pl. 12, fig. 2; Jour. Paleont., 1927, vol. 1, p. 161, pl. 28, fig. 9; 1937, Cushman Lab. Foram. Res., Spec. Publ. 9, p. 66, pl. 8, fig. 8.

Small but typical specimens of this species occur in unit 7. The species was not mentioned by Cushman & Stainforth. The distinct keel with fine hooks at the base of the



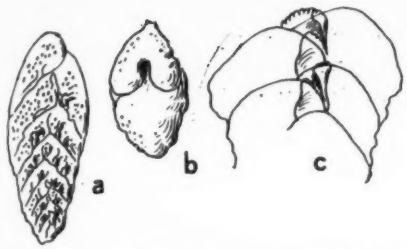
TEXT-FIG. *30—Bolivina mexicana* Cushman. Specimens from unit 7. (*a,b*) external view, distribution of pores partly indicated, ×65; (*c*) apertural view, ×65; (*d*) final chamber with toothplate, ×240.

last-formed chambers, the oblique and curved sutures, and the very fine protopores are typical for this species. Moreover the toothplate shows a slightly curved back and a very large free folded part which flares into the aperture. The aperture is high up on the chamber and very narrow. The transverse section is rhombiform with short acute keels. The pores are found all over the chamber walls.

BOLIVINA BYRAMENSIS Cushman Text-fig. 31

Bolivina coelata Cushman var. *byramensis* CUSHMAN, 1923, U. S. Geol. Surv., Prof. Paper 133, p. 19, pl. 1, fig. 9.
Bolivina byramensis CUSHMAN, 1937, Cushman Lab. Foram. Res., Spec. Publ. 9, p. 69, pl. 8, fig. 18–20.

This species, known from the Oligocene of Texas and Venezuela, was represented by several specimens in unit 7. It was not mentioned by Cushman & Stainforth. Although the specimens are slightly more elongate and somewhat thicker in transverse section than those described by Cushman, they seem to belong to this species with its typical ornamentation. Similar specimens occur in the Eocene and Lower Oligocene of



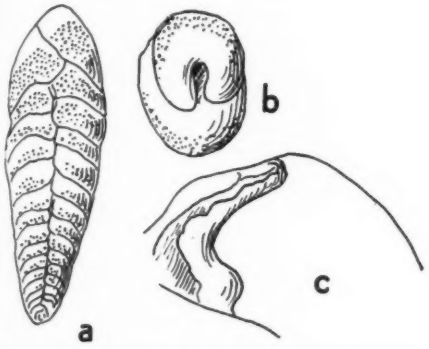
TEXT-FIG. *31—Bolivina byramensis* Cushman. (*a,b*) side view and apertural view of specimen from unit 7, ×65; (*c*) toothplates in a specimen from the Eocene of Holland, ×115.

Holland. The pores are very distinct in the smooth area between the ornamentation. In the Dutch specimens the toothplate is distinctive, with a narrow free folded part and the attached part crenulated at the top.

BOLIVINA GRACILIS
Cushman & Applin
Text-fig. 32

Bolivina gracilis CUSHMAN & APPLIN, 1926, Amer. Assoc. Petr. Geol., Bull., vol. 10, p. 167, pl. 7, fig. 1,2; HOWE & WALLACE, 1932, Louisiana Geol. Surv., Bull., vol. 2, p. 57; CUSHMAN, 1935, U. S. Geol. Surv., Prof. Paper 181, p. 37, pl. 14, fig. 8–10; 1937, Cushman Lab. Foram. Res., Spec. Publ. 9, p. 59, pl. 7, fig. 22,23.

This species was found rarely at locality 7. It was not mentioned by Cushman & Stainforth. It is a typical Cocoa sands (Eocene, Alabama) species, and the specimens from Ecuador are identical. The slender test, the numerous low chambers, the hyaline walls with pores covering only the basal parts of the chamber-walls, and the oval transverse section are all typical features of this distinctive species, as is the toothplate, bent backward with a strongly curved back and narrow free folded part.



TEXT-FIG. *32—Bolivina gracilis* Cushman & Applin. Specimens from unit 7. (*a,b*) external views, ×80; (*c*) last formed chamber with toothplate, ×300.

Genus BOLIVINOIDES Cushman, 1927

This genus comprises those *Bolivinas* which show axial overlapping of part of each chamber over its basal suture, covering part of the preceding chamber. The loop-shaped aperture, simple bolivine toothplate, and finely porous wall of all these species indicate a very close relationship to *Bolivina*. The genus is not restricted to the Upper Cretaceous but ranges up to modern times [e.g. *Bolivinoides robusta* (Brady)]. Many Tertiary species, hitherto included in *Bolivina*, should actually be placed in *Bolivinoides*, which might be regarded as a subgenus of *Bolivina* rather than a separate genus. (See Hofker, 1952.)

BOLIVINOIDES ALAZANENSIS (Cushman)
Text-fig. 33

Bolivina alazanensis CUSHMAN, 1926, Cushman Lab. Foram. Res., Contr., vol. 1, p. 82, pl. 12, fig. 1; CUSHMAN & STAINFORTH, 1951, Jour. Paleont., vol. 25, p. 155, pl. 26, fig. 57.

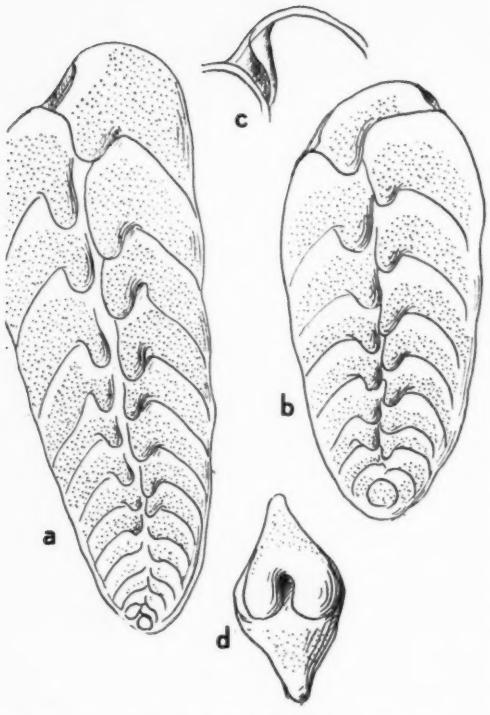
This is a characteristic *Bolivinoides;* an axial part of each chamber overlaps its contact with the preceding one. The pores are fine, covering most of the chamber-walls, including the overlapping portions; only a distal area on each chamber is poreless. The transverse section is lozenge-shaped, the chambers run backwards at the margin, and the toothplate is small and simple.

The microspheric is more slender than the megalospheric generation: it begins with a proloculus of about 10μ diameter, and is followed by 12–14 pairs of biserial chambers, whereas the megalospheric form starts with proloculus of about 24μ diameter and is followed by 8–9 pairs of biserial chambers. As in the Recent *Bolivinoides robusta* the microspheric form occurs more commonly.

B. alazanensis was noted at localities 7 and 10.

Genus SPIROBOLIVINA Hofker, n. gen.

Genotype: *Bolivinopsis pulchella* Cushman & Stainforth, 1947, Cushman Lab. Foram. Res., Contr., vol. 23, p. 78, pl. 17, fig. 4,5.



TEXT-FIG. *33—Bolivinoides alazanensis* (Cushman). Specimens from locality 8, all (*a*) microspheric; (*b*) megalospheric; (*c*) apertural face; (*d*) toothplate in final chamber.

Test formed as in *Bolivina*, biserial chambers meeting axially at about 90°, except for the initial part of the test, which appears to be planispirally coiled, but in reality is also biserial. Wall calcareous with distinct pores. Toothplates in all chambers, including the coiled portion, bolivine, inconspicuous, their orientation changing by 180° in successive chambers. Aperture loop-shaped.

A new genus has to be erected since the type species of *Bolivinopsis* is an arenaceous form, the name being synonymous with *Spiroplectammina*. *Spirobolivina* will accommodate calcareous species with the characters given above, hitherto referrred to *Bolivinopsis*.

Spirobolivina stands in respect to *Bolivina* as *Heterohelix* to *Gümbelina*. Both forms seem to be end-stages of their lineages. *Heterohelix* forms the end-stage of the *Gümbelina striata* lineage. This group began in the Cenomanian-Turonian with trimorphic forms, but they soon became dimorphic and apogamic, the size of the proloculus decreasing gradually. The end-forms with very minute proloculi were followed in the Maestrichtian and early Tertiary by a series with planispiral initial chambers.

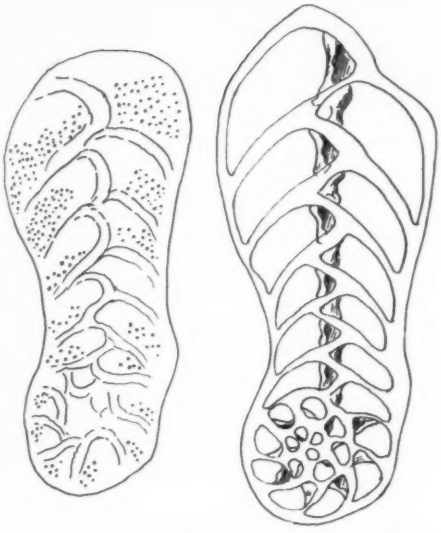
Evidently there was a lineage of *Bolivina* in which a similar phenomenon occurred, though in this instance the spirally coiled end-stage was dimorphic, not apogamic. Probably this was the group of forms with very simple toothplates, the lineage of *Bolivina incrassata* Reuss, which in the Upper Maestrichtian of Europe and America developed wholly apogamic forms. In the Lower Tertiary the apogamic *Bolivina plaita* Cushman and *B. hiltermanni* Hofker and the dimorphic *Spirobolivina pulchella* (Cushman & Stainforth) may represent end-stages of the *B. incrassata* lineage. In the Middle Tertiary the whole group became extinct, giving place to forms with more complicated toothplates. The appearance of coiled end-forms may be a regressive development, indicating that the most ancient forms of both *Gümbelina* and *Bolivina* were also coiled.

Cushman & Stainforth placed *Spirobolivina pulchella* in the Heterohelicidae, under its original identification as a *Bolivinopsis*. Apart from the inapplicability of the name *Bolivinopsis* to a calcareous form (the test of the genotype, *B. capitata* Yakovlev, is arenaceous), the presence of toothplates and the loop-shaped aperture clearly prove that *Spirobolivina pulchella* is not a heterohelicid species.

SPIROBOLIVINA PULCHELLA
(Cushman & Stainforth)
Text-fig. 34,35

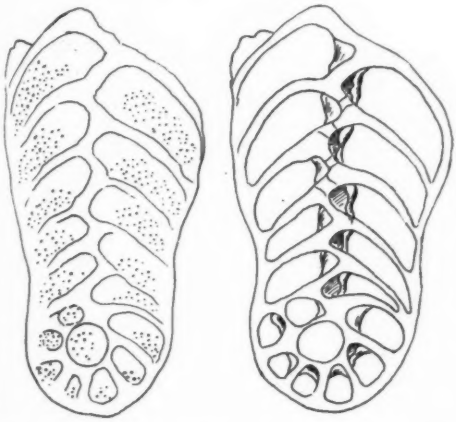
Bolivinopsis pulchella CUSHMAN & STAINFORTH 1947, Cushman Lab. Foram. Res., Contr., vol. 23, p. 78, pl. 17, fig. 4,5; 1951, Jour. Paleont., vol. 25, p. 149, pl. 26, fig. 30,31.

This species is abundant at localities 5 and 6. In the microspheric form a very small proloculus (8μ diameter) is followed by two and a half whorls of chambers in an involute coil. Sutures are thick and the walls carry small but distinct pores only near the proximal sutures. Then a biserial arrangement of the chambers begins, also with thickened sutures and pores only on the proximal parts



TEXT-FIG. 34—*Spirobolivina pulchella* (Cushman & Stainforth). Microspheric form from locality 6, ×180. External view and longitudinal section, the latter showing the alternation of toothplates in the spiral as well as the biserial portion.

of the chamber-walls. Near to the spiral suture or the biserial axis every chamber shows a primitive but very conspicuous toothplate, which has a narrow free folded part with slightly crenulate border. In the coiled as well as the biserial part, each successive toothplate is at an angle of 180° to the preceding one, thus indicating that even in the spiral part the real arrangement of the chambers is biserial. In the megalospheric form the proloculus measures about 30μ and is followed by a single whorl of chambers, but other details are the same except for thicker axial sutures.



TEXT-FIG. 35—*Spirobolivina pulchella* (Cushman & Stainforth). Megalospheric form from locality 6. External view and longitudinal section, the latter showing alternation of the toothplates in the spiral as well as the biserial portion. Both ×180.

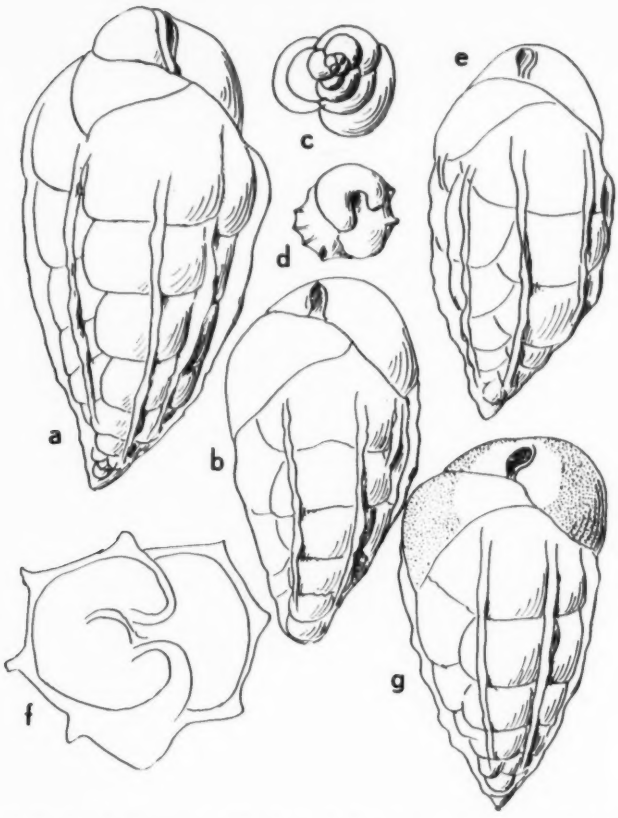
Family BULIMINIDAE
Genus PRAEBULIMINA Hofker, 1951

Tests with mostly four chambers in a whorl, but in some species from the Lower Tertiary becoming triserial in the last formed part of the test, at least in the megalospheric form. Pores always very fine and densely placed. Aperture loop-shaped, sutural. Toothplate always present, simple, with narrow free folded part. Walls mostly somewhat opaque. The genus begins in the lower part of the Upper Cretaceous and becomes extinct in the Lower Tertiary. Many of its species have been placed in *Bulimina*, but do not belong there since in that genus the toothplate is very complicated and forms part of the apertural face.

PRAEBULIMINA JACKSONENSIS (Cushman)
Text-fig. 36,37

Bulimina jacksonensis CUSHMAN, 1925, Cushman Lab. Foram. Res., Contr., vol. 1, p. 6, pl. 1, figs. 6,7; CUSHMAN & STONE, 1947, ibid., Spec. Publ. 20, p. 13, pl. 2, fig. 11; STAINFORTH, 1948, Jour. Paleont., vol. 22, p. 127, pl. 24, fig. 12; ——, CUSHMAN & STAINFORTH, 1951, ibid., vol. 25, p. 151, pl. 26, fig. 43.

This well-known, strongly costate species was abundant at locality 6. It is a large species, the test always tapering towards the apertural end, more or less acute at the initial end (more acute in the microspheric form): triserial in the later chambers, but mostly quadriserial in the early chambers, at least in the microspheric form; aperture loop-shaped, showing a simple toothplate with narrow free folded part and broad attached part, always fixed to the axial wall of the chambers: wall very finely porous all over except for an area around the aperture. All these characters do not point to *Bulimina*, but to *Praebulimina*, or at least to a derivative of that Cretaceous genus. All microspheric specimens, not only from Ecuador



TEXT-FIG. *36*—*Praebulimina jacksonensis* (Cushman). Specimens from unit 6. (*a*) microspheric test; (*b,e,g,*) megalospheric tests; (*c*) initial part of microspheric form; (*d*) apertural view; (*f*) transverse section. (*d*) ×30, other ×65.

but also from the Eocene Cocoa sands of Alabama, show these typical features.

Genus BULIMINA d'Orbigny, 1826

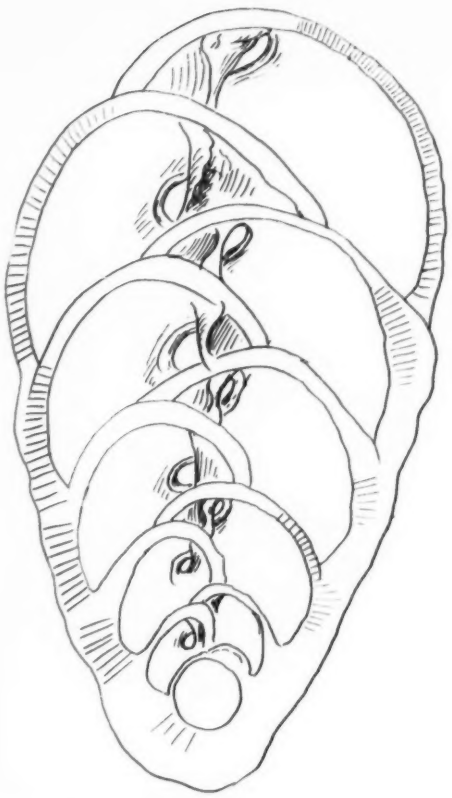
Triserial throughout, with chambers which in most cases show a rounded outer wall, not angled as in *Reussella;* pores in some cases fine, in other cases more scattered and more distinct, but never coarse. Walls always hyaline. Aperture always loop-shaped, sutural, with a real toothplate in all forms. Toothplate simple in more primitive forms, with an attached part and a free folded part. More advanced species become more complicated, with part of the attached portion formed into a siphon which open near to the aperture in a fine toothplate foramen.

BULIMINA CACUMENATA
Cushman & Parker
Text-fig. 38

Bulimina cacumenata CUSHMAN & PARKER, 1936, Cushman Lab. Foram. Res., Contr., vo', 12, p. 40, pl. 7, fig. 3.

This species is common at locality 5, though not mentioned by Cushman & Stainforth. The specimens are very typical and apparently have been confused with *Stainforthia dalliformis*, which they resemble at low magnification. They were compared with tests from the Eocene Cocoa sands of Alabama and are identical.

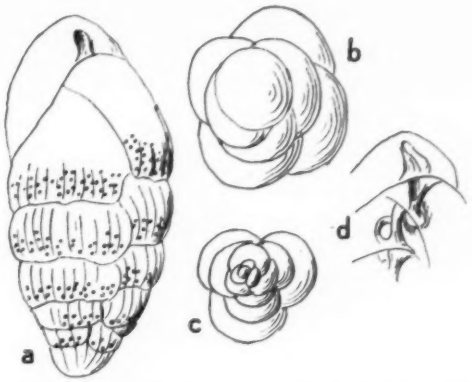
The type description is "Test small, somewhat fusiform, greatest width slightly above the middle, gradually tapering to a long, subacute point; chambers numerous, 6-7



TEXT-FIG. 37—*Praebulimina jacksonensis* (Cushman). Longitudinal section of specimen from unit 6, showing toothplates, ×235.

whorls, those of the last whorl somewhat inflated, arranged in a slightly twisted series, those of adjacent series meeting in a zigzag line; sutures distinct in the upper part, obscure in the lower part of the test, very slightly depressed; wall, except for the last whorl and occasionally for the next to the last, covered with irregular, low, closely set costae, last whorl smooth, coarsely perforate; aperture loop-shaped, with a slight lip. Length 0.20–0.23 mm.; diameter 0.10–0.11 mm."

The species is recorded from the Paleocene and Eocene. In both microspheric and megalospheric generations the test is wholly triserial, as in a true *Bulimina*. The walls are very hyaline. The pores are only found on the proximal part of each chamber. Each wide loop-shaped septal foramen carries a



TEXT-FIG. 38—*Bulimina cacumenata* Cushman & Parker. (*a*) side view; (*b*) initial part, megalospheric; (*c*) initial part, microspheric; (*d*) toothplates in last formed chambers. All ×180.

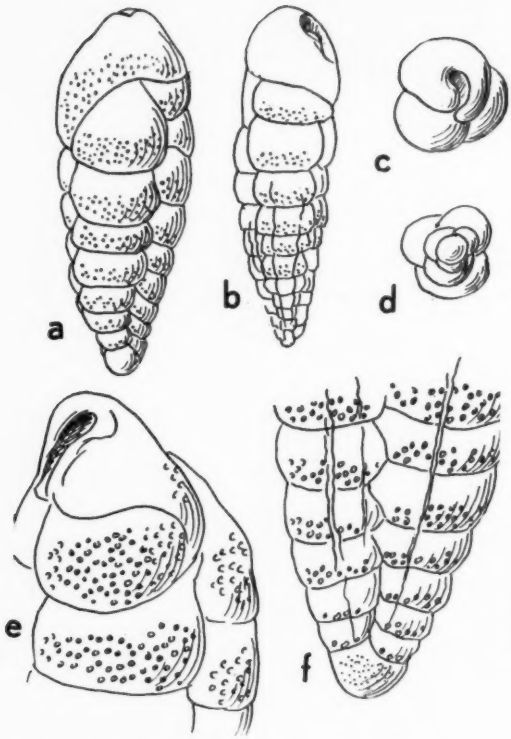
tapering, almost tubular toothplate running to the previous aperture, with a very narrow folded part.

BULIMINA LINEATA
Cushman & Stainforth
Text-fig. 39,40

Bulimina lineata CUSHMAN & STAINFORTH, 1947, Cushman Lab. Foram. Res., Contr., vol. 23, p. 79, pl. 17, fig. 12; 1951, Jour. Paleont., vol. 25, p. 153, pl. 26, fig. 45.

This species is common at locality 6. To the original description may be added: the basal sutures are horizontal; the costae on the walls are very fine and often nearly invisible, and contrary to the type-figures are never found on the last two or three sets of chambers; the pores are distinct and coarse, limited to the proximal part of each chamber; fine pores are only seen on the proloculus; in section the pores are slightly funnel-shaped. The toothplates, well preserved in this material, show a rather narrow attached part and a broad, flaring free folded part with a crenulated border; this border often protrudes slightly from the aperture.

In the toothplate as well as the regularly placed chambers this species shows a striking resemblance to *Bulimina trigonalis* Ten Dam from the Paleocene of Holland (1944, Netherlands Geol. Stichting, Meded., ser. C, vol. 5, n. 3, p. 112, pl. 3, fig. 16,17); the two species must be closely allied.



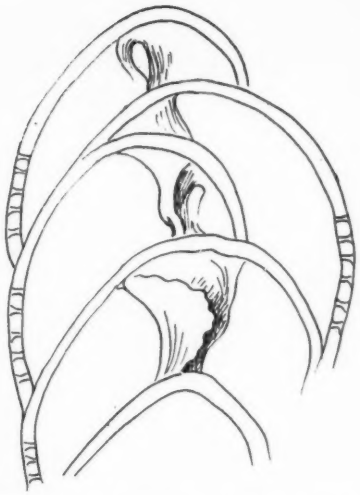
TEXT-FIG. *39—Bulimina lineata* Cushman & Stainforth. Specimens from locality 6. (*a*) megalospheric form; (*b*) microspheric form; (*c*) apertural view; (*d*) initial chambers; (*e*) apertural end, showing pores; (*f*) initial end, showing pores, especially the very fine pores on the megalospheric proloculus. *a–d*, ×80: *e,f* ×235.

BULIMINA PSEUDOVATA Hofker, n. sp.
Text-fig. 41,42

Bulimina ovata CUSHMAN & STAINFORTH, 1951 (not d'Orbigny, 1846). Jour. Paleont., vol. 25, p. 151, pl. 26, fig. 44.

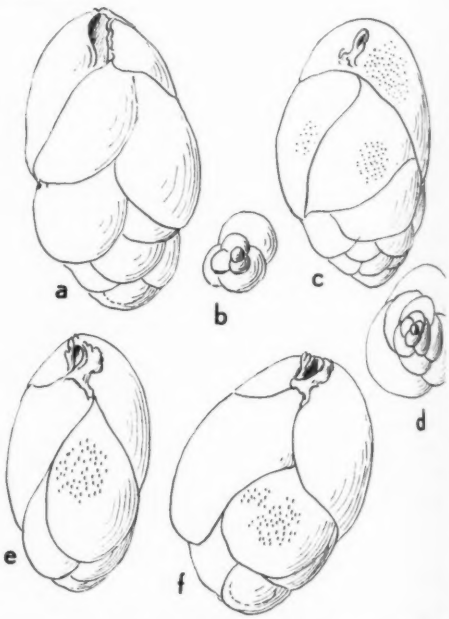
This species is common at locality 7.

There has been much confusion regarding *Bulimina ovata* d'Orbigny. Cushman & Parker mention its occurrence from Eocene to Recent (1947, p. 107), but such a long range for any foraminiferal species is always very questionable. It has already been pointed out (Hofker, 1950, p. 252–254) that the species from Rimini is a *Protoglobobulimina*, and the same is true of the European Miocene form. Topotypes from the Miocene at Nussdorf near Vienna are definitely *Protoglobobuliminas*. D'Orbigny's species

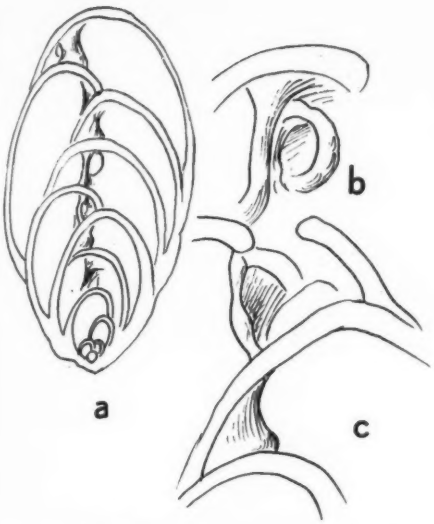


TEXT-FIG. *40—Bulimina lineata* Cushman & Stainforth. Longitudinal sections showing the toothplates, ×240.

therefore, is not a *Bulimina* at all. The species from Ecuador, however, is a true *Bulimina*.



TEXT-FIG. *41—Bulimina pseudovata*, n. sp. (*a,c*) External views of cotypes from locality 7; (*b,d*) views of initial chambers; (*e,f*) for comparison, topotypes from Rimini of *Protoglobobulimina ovata* d'Orb., showing its elongate pores. All ×65.



TEXT-FIG. 42—*Bulimina pseudovata*, n. sp. (*a*) longitudinal section, ×80; (*b,c*) enlarged views of this section, showing toothplates, ×300. Topotype from locality 7.

In *Protoglobobulimina ovata* (d'Orbigny) the aperture is wide, rounded, with the typical collar, and the toothplate is a real plate though much reduced in its free folded part: the pores are of the typical elongate type. In contrast the Ecuador species shows a loop-shaped aperture without a collar. The last formed chambers are not so strongly elongate and overlapping. The toothplate is a primitive bulimine plate with narrow free folded part, slightly curved at the back. The pores are small and round. The initial chambers of the microspheric form are triserially arranged as in typical *Bulimina*.

This species from Ecuador is here named *Bulimina pseudovata*, n. sp., and described as follows: test of medium size, nearly twice as long as broad, oval in the megalospheric form, ovoid with acute initial end in the microspheric form, the broadest part at about the middle of the test. Test consists of two or three whorls in the megalospheric form, about five whorls in the microspheric form. Chambers vary from distinctly inflated in the adult to nearly flush in the microspheric whorl. Sutures distinct to indistinct, slightly depressed. Wall smooth, always shining, thin in the last formed whorls, with fine, somewhat scattered round pores which are not elongate, and never placed in longitudinal lines. Aperture elongate, loop-shaped, sutural, with slightly raised borders. Toothplate somewhat flaring, with slightly curved back, not protruding from the aperture. Length about 0.60 mm, breadth about 0.36 mm.

Type locality.—On Rio Zapallo Grande at a point 9 km. ESE. of Telembi, Ecuador. Type-level: Upper Eocene. Type specimens have been deposited in the Cushman Collection, U. S. National Museum, P4906 (3 syntypes).

BULIMINA SECAENSIS
Cushman & Stainforth
Test-fig. 43

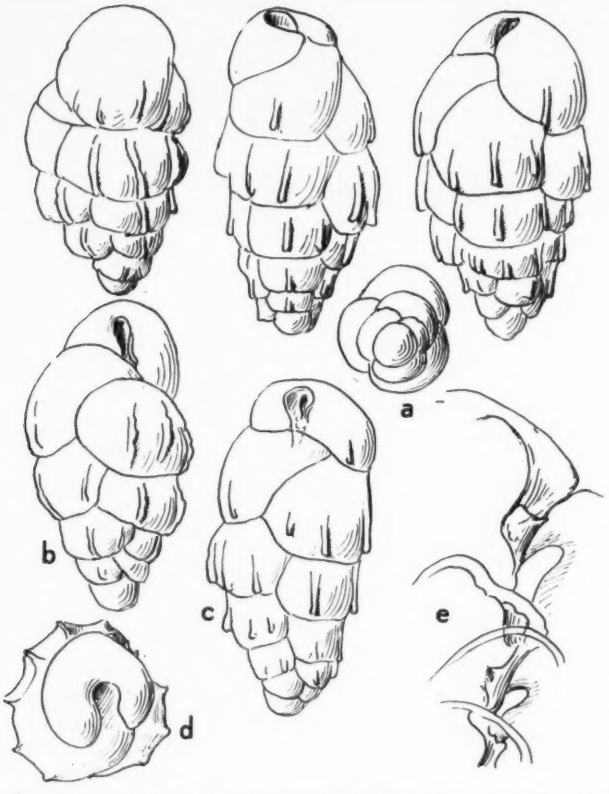
Bulimina secaensis CUSHMAN & STAINFORTH, 1947, Cushman Lab. Foram. Res., Contr., vol. 23, p. 79, pl. 17, fig. 9,10; 1951, Jour. Paleont., vol. 25, p. 152, pl. 26, fig. 48,49.

This species is distinguished by the following characters: each chamber shows three or four costae which do not run into one another, but end at the proximal suture in a short blunt part, nearly a spine; the transverse sutures are horizontal; the aperture is a wide loop-shaped opening connected with a narrow toothplate which runs from the previous aperture and forms a flaring attached part around the border of the aperture, whereas the free folded part remains short and does not reach the aperture. The specimens are triserial throughout as in a true *Bulimina*.

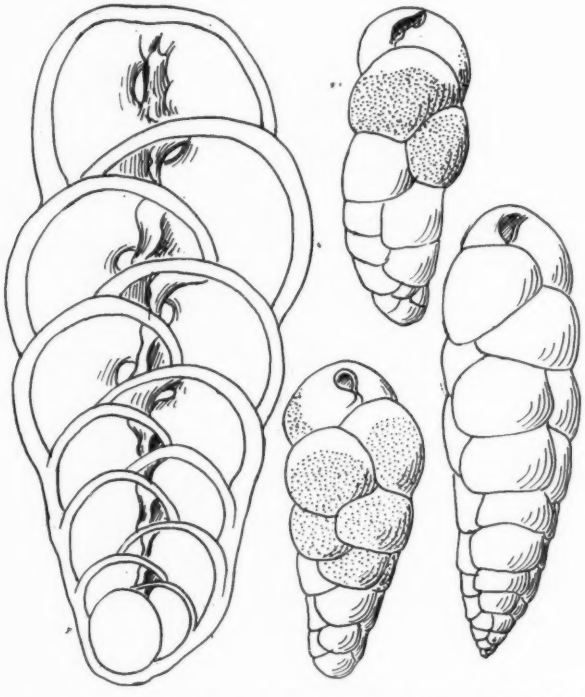
BULIMINA PERUVIANA
Cushman & Stone
Text-fig. 44

Bulimina peruviana CUSHMAN & STONE, 1947, Cushman Lab. Foram. Res., Spec. Publ. 20, p. 14, pl. 2, fig. 16; —— CUSHMAN & STAINFORTH, 1951, Jour. Paleont., vol. 25, p. 154.
Bulimina affectata CUSHMAN & STAINFORTH, 1951, ibid., vol. 25, p. 154, pl. 26, fig. 40,41.

This species is common at locality 8. The slightly twisted rows of chambers, the nearly horizontal sutures, the form of the chambers (somewhat broader than high), and the elongate form of the test are all characters resembling those of *Bulimina trigonalis* Ten Dam from the Paleocene of the Netherlands (see Hofker 1950, p. 149–151). There is a definite difference in that the test of B. *peruviana* is much larger and its pores are



TEXT-FIG. *43*—*Bulimina secaensis* Cushman & Stainforth. Specimens from locality 5, Upper row side views, (*a*) initial view of the same specimen, ×65; (*b,c*) two other tests, ×65; (*d*) apertural view, ×65; (*e*) part of longitudinal section, showing toothplates, ×180.



TEXT-FIG. *44*—*Bulimina peruviana* Cushman & Stone, Three tests from unit 8, one microspheric, ×65; longitudinal section showing toothplates, ×180.

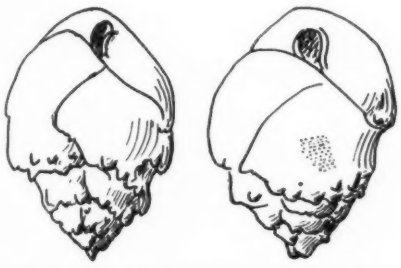
finer and more closely packed. However, the close relationship of the two species is emphasized by the similarity of their toothplates: those of *B. peruviana* are primitive, with a broader attached part and narrower free folded part, which is slightly dentate only at its upper border, the long border being smooth.

Cushman & Stainforth only recorded a single specimen of *B. peruviana* at locality 3, but determined the species as being common at locality 8 under a new name, *B. affectata*. I compared this species with topotypes of *B. peruviana* from the Eocene Chira shale of Peru but could not detect any significant differences. Hence *B. affectata* Cushman & Stainforth, 1951 appears to be a synonym of *B. peruviana* Cushman & Stone, 1947.

BULIMINA IMPENDENS
Parker & Bermudez
Text-fig. 45

Bulimina impendens PARKER & BERMUDEZ, 1937, Jour. Paleont., vol. 11, p. 514, pl. 58, fig. 7,8; CUSHMAN & PARKER, 1947, U. S. Geol. Surv., Prof. Paper 210d, p. 100, pl. 23, fig. 6,7.

This species was not mentioned by Cushman & Stainforth, though several well preserved specimens were found at locality 6. The length, 0.42 mm., is the same as the type specimens from the Eocene of Cuba. The pores are very fine, the test quite hyaline. The proximal borders of the chambers are typically truncated and somewhat granulose, the granulations often growing out into small blunt spines, which cover the initial part of the test. It is possible that the single specimen mentioned by Cushman & Stainforth from locality 7 as *B. stalacta* Cushman & Parker also belongs to *B. impendens*.



TEXT-FIG. *45*—*Bulimina impendens* Parker & Bermudez. Two tests from unit 6, ×80.

Family BULIMINELLIDAE
Genus BULIMINELLA Cushman, 1911

The characters of the genotype, *Buliminella elegantissima* (d'Orbigny) limit this genus to those species in which the walls are hyaline and pierced by very fine, closely set pores, with more than three chambers in a whorl, and with a very complicated toothplate: this toothplate not only divides the distal part of the chamber into several compartments, but also forms a large flaring part of the apertural face of the chamber-wall, which is not pierced by pores.

Species with these characters are only known from the Lower Tertiary upward. Species in the Upper Cretaceous, hitherto referred also to *Buliminella*, show quite different features and should be placed in *Praebulimina* Hofker. There are some Tertiary species, viz. "*Bulimina*" *jacksonensis* Cushman, which show the characteristics of *Praebulimina*, at least in the microspheric form, and which I place in that genus.

BULIMINELLA OBESA
Cushman & Stainforth
Text-fig. 46

Buliminella peruviana Cushman & Stone var. *obesa* CUSHMAN & STAINFORTH, 1951, Jour. Paleont., vol. 25, p. 150, pl. 26, fig. 35.

This species is common at locality 5. A

TEXT-FIG. *46*—*Buliminella obesa* Cushman & Stainforth. General view of a test, showing the toothplate of the final chamber and the apertural face formed by this plate, with its distinctive honeycomb ornamentation. ×300. specimen from unit 5.

close study of the finer characters revealed that it is quite a different species from *B. peruviana*, not merely an inflated variety. For in *B. peruviana* the poreless part of the apertural face, which is formed by the toothplate as in all true *Buliminella*, is totally structureless, whereas in *B. obesa* it invariably shows a very typical fine honeycomb structure. Moreover the toothplate, irregularly built as in all *Buliminella*, shows large outgrowths in *B. obesa*, protruding slightly from the aperture.

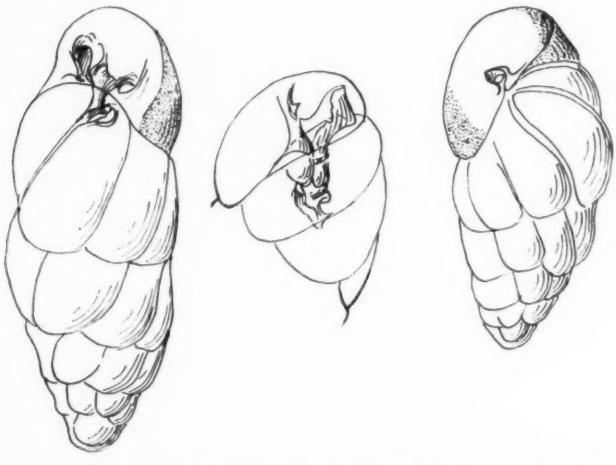
BULMINELLA CHIRANA
Cushman & Stone
Text-fig. 47

Buliminella chirana CUSHMAN & STONE, 1947, Cushman Lab. Foram. Res., Spec. Pub. 20, p. 13, pl. 2, fig. 10; CUSHMAN & STAINFORTH, 1951, Jour. Paleont., vol. 25, pl. 26, fig. 36.

This species is abundant at locality 8. Specimens were compared with topotypes from the Eocene Chira shale of Peru and are identical. There are about five or six narrow and high chambers in a whorl. The pores are very fine and the walls relatively thick, making the tests appear more opaque than in most species of *Buliminella*. The sutures are distinct and slightly limbate, though inflation of the chambers makes them appear depressed. The apertural face is rather broad, smooth and poreless, formed by the very flaring toothplate behind the small, loop-shaped, sutural aperture. The toothplate is of the irregular and highly complicated shape of true *Buliminella*.

Genus BULIMINELLITA Cushman & Stainforth, 1947

This genus, recorded only in the Eocene, has a calcareous test covered all over with very fine protopores, the aperture always terminal, and a toothplate which in all species observed consists of a tubular plate with one side open, running from one foramen to the next, even in the initial part of the test. Though the test shows an external resemblance to *Buliminella*, the shape of the toothplate indicates a different alliance. In *Buliminella* the toothplate is always much more complex, forming part of the apertural face: but in *Buliminellita* the toothplate shows from the beginning the typical character of many Uvigerinidae. The arrangement of chambers, not triserial but mostly quadriserial, differs from *Uvigerina* but resembles that of the Cretaceous *Praebulimina*. There are indications that *Eouvigerina* (clearly not a heterohelicid genus, since all its species show very well developed toothplates) developed in the late Cretaceous into true Uvigerinidae. Thus *Buliminellita* is closely related to *Uvigerina* and may be the offspring of some form near *Praebulimina* and *Eouvigerina*.

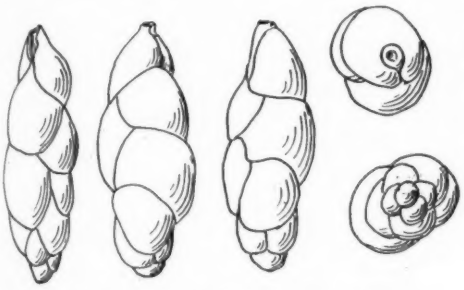


TEXT-FIG. 47—*Buliminella chirana* Cushman & Stone. Views of three tests from unit 8, ×180. The toothplate is indicated, a complicated one, as is typical for the genus.

BULIMINELLITA NUDA
(Howe & Wallace)
Text-fig. 48

Buliminella basistriata Cushman & Jarvis var. *nuda* HOWE & WALLACE, 1932, Louisiana Geol. Surv., Bull. no. 2, p. 60, pl. 11, fig. 4; CUSHMAN, 1946, Cushman Lab. Foram. Res., Spec. Pub. 16, p. 22, pl. 4, fig. 30.

This species occurs abundantly at locality 5a, but is not identical with *Buliminellita mirifica* from locality 5; it was not mentioned by Cushman & Stainforth. *B. nuda* differs



TEXT-FIG. *48—Buliminellita nuda* (Howe & Wallace). Specimens from unit 5a. Side, initial and apertural views.

from *B. mirifica* in the following points: the test is much larger (length in *B. mirifica* up to 0.26 mm., in *B. nuda* 0.55 mm.); the walls are much thicker and thus the tests are more opaque, yet they do not belong to *Virgulina* ("*Cassidella*"), since the structure is distinctly radiate and not granulate; the chambers in *B. nuda* are always much broader, since there are four to five chambers per whorl in *B. mirifica*, only two or three in *B. nuda*. The test of *B. nuda* is of a more slender build, about three times as long as broad, whereas *B. mirifica* is little more than twice as long as broad.

Our form has been thought to be a variety of *Buliminella basistriata* without the longitudinal striae. However, none of the Ecuador specimens nor any of those from the stratigraphically equivalent Chira shale of Peru show striae. The variety is herewith elevated to species rank.

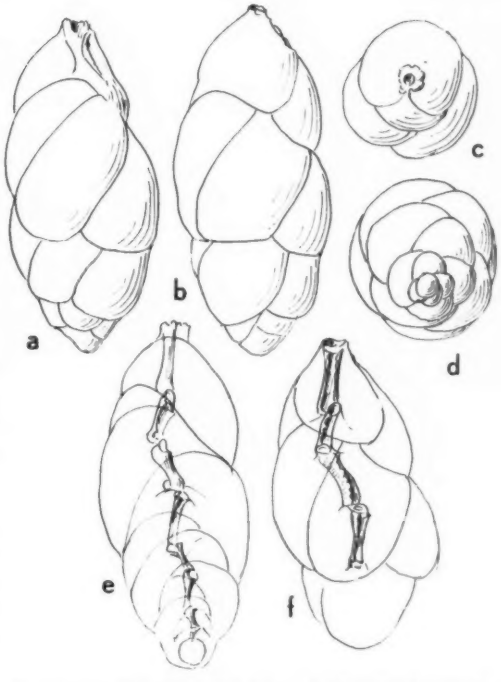
BULIMINELLITA MIRIFICA
Cushman & Stainforth
Text-fig. 49,50

Buliminellita mirifica CUSHMAN & STAINFORTH, 1947, Cushman Lab. Foram. Res., Contr., vol. 23, p. 78, pl. 17, fig. 6–8; 1951, Jour. Paleont., vol. 25, p. 151, pl. 26, fig. 37–39.

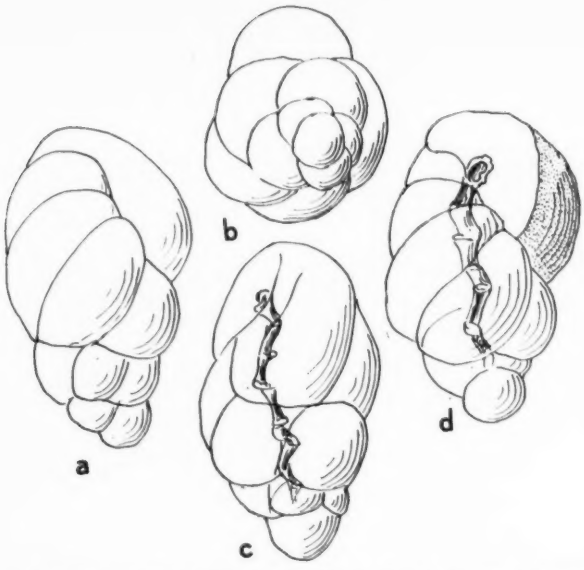
Buliminellita parva DROOGER, 1953, Koninkl. Nederl. Akad. Weten., Proc., ser. B, 56, no. 1, p. 100, pl. 1, fig. 3.

This species is very common at locality 5. It is very small (length of microspheric tests up to 0.26 mm., of megalospheric tests up to 0.23 mm.) with very hyaline and very thin walls. The pores, covering the whole wall, are extremely fine. In the microspheric test there are four chambers to a whorl, in the megalospheric test three or four chambers to a whorl. The proloculus of the B-generation (possibly the A_1-generation) measures about 16–18μ, whereas in the megalospheric form (possibly the A_2-generation) it measures up to 48μ. The sutures are fairly oblique, especially in the generation with small proloculus.

In the first sets of chambers the aperture is somewhat suturally placed, loop-shaped



TEXT-FIG. *49—Buliminellita mirifica* Cushman & Stainforth. (*a,b*) different side views of a single test; (*c*) apertural view; (*d*) initial portion; (*e*) section of megalospheric specimen with small proloculus, showing toothplates; (*f*) similar section of test with very large proloculus. All ×180.



TEXT-FIG. *50*—*Buliminellita mirifica* Cushman & Stainforth. Specimens from locality 5a. (*a,b*) external views; (*c*) same test, showing the toothplates; (*d*) abnormal test in which the apertures are not yet terminally place. All ×180.

with a fringed border; in the later chambers it becomes terminal, since the sutural part of it is closed. A fine closing-suture always remains. Attached to the aperture is a toothplate running back to the previous aperture. The toothplate is long and narrow, with both borders free and slightly fringed as in many Uvigerinidae. Even in chambers with sutural apertures the toothplate has this form. The terminal apertures may show a short neck.

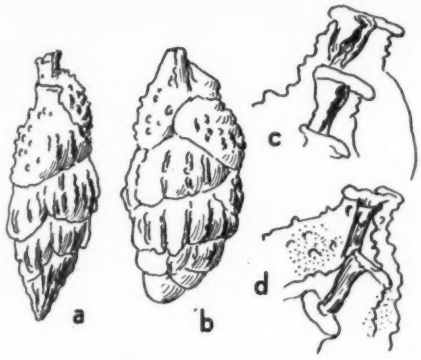
The primitive condition of the toothplate, the very fine pores, the sutural loop-shaped form of the aperture in the early chambers (even in the later chambers in the megalospheric form) and the arrangement of the chambers in whorls of four all point to the Upper Cretaceous genus *Praebulimina*. One may describe this species as a *Praebulimina* in which the aperture eventually becomes terminal. It is parallel to *Pyramidina* among the Reussellidae. On the other hand the species is remarkable in the resemblance of its toothplate to those of some Uvigerinidae. Taxonomically it has to be placed close to *Praebulimina* or *Uvigerina*, and the simple toothplate shows that it has nothing to do with *Buliminella*.

Drooger has recognized this species in the Upper Eocene of Curaçao and Bonaire, N.W.I. He treats it as synonymous with *Uvigerinella parva* Cushman & Jarvis (also *Uvigerina westermanni* Pijpers) but makes no comments on the finer structure in support of this synonymy.

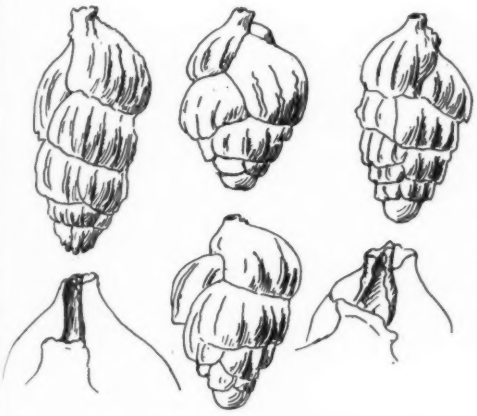
Family UVIGERINIDAE
Genus EUUVIGERINA Thalmann, 1952
EUUVIGERINA GARDNERAE (Cushman)
Text-fig. 51

Uvigerina gardnerae CUSHMAN, 1926; for references see CUSHMAN, 1946, Cushman Lab. Foram. Res., Spec. Pub. 16, p. 29.

This species is common at locality 5. It was not mentioned by Cushman & Stainforth, but possibly included in *Uvigerina yazooensis* Cushman. The last formed chambers always show only blunt spinose ornamentation and the earlier ones irregularly developed costae, evidently formed by fusion of the blunt spines. The test is more slender than that of *E. yazooensis*. The toothplate is distinctive, very primitive with one border attached to the axial wall of the chamber, and with a very narrow free folded part with slightly dentate border. The neck is poreless. The Ecuador species is identical



TEXT-FIG. *51—Euuvigerina gardnerae* (Cushman). (*a*) microspheric form; (*b*) megalospheric form; (*c,d*) terminal sections, showing toothplates. *a,b* ×65, *c,d* ×180. Specimens from locality 5a.



TEXT-FIG. *52—Euuvigerina yazooensis* (Cushman). Specimens from locality 5a. External views of four tests, ×65; two apertural views showing toothplates, ×180.

in all ways with that of the Jackson formation and the Cocoa sands.

EUUVIGERINA YAZOOENSIS (Cushman)
Text-fig. 52,53

Uvigerina yazooensis CUSHMAN, 1933: see CUSHMAN & STAINFORTH, 1951, Jour. Paleont., vol. 25, p. 155, pl. 26, fig. 61.

This species is characterized by prominent costae, even on the wall of the last chamber. At the basal sutures of the chambers each of the costae ends in a blunt projection, giving the periphery a somewhat dentated character. The toothplate is typical for *Euuvigerina*, forming a half-tube with one border attached to the axial wall of the chamber. The species is common at locality 5.

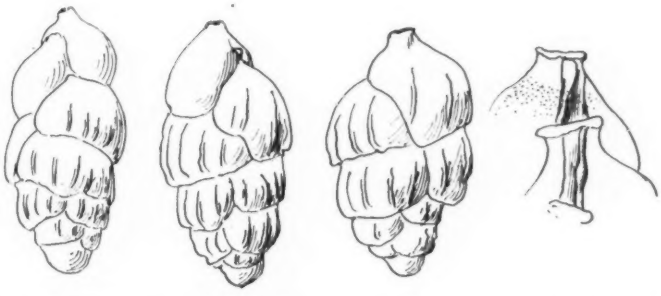
EUUVIGERINA COCOAENSIS (Cushman)
Text-fig. 54

Uvigerina cocoaensis CUSHMAN, 1925: see CUSHMAN, 1946, Cushman Lab. Foram. Res., Spec. Pub. 16, p. 28, pl. 5, fig. 15–20.

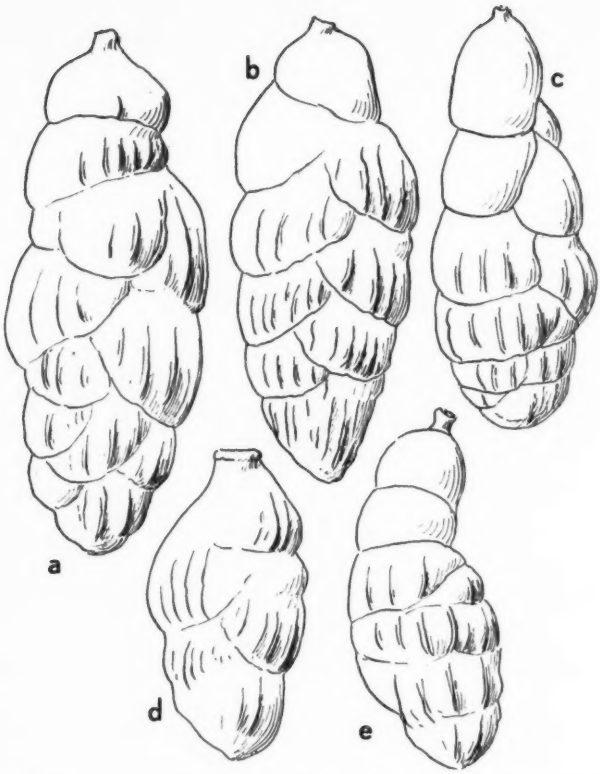
Many specimens of this characteristic species were found at localities 4 and 8, though not mentioned by Cushman & Stainforth. They have been compared with topotypes from the Eocene Cocoa sands of Alabama and are identical. Specimens from locality 5a may belong to this species, though they suggest *Uvigerina vicksburgensus* Cushman & Ellisor. They also show the typical toothplates of *E. cocoaensis* (Cushman), with a relatively broad free folded part.

EUUVIGERINA COOKEI (Cushman)
Text-fig. 55

Uvigerina cookei CUSHMAN, 1935, U. S. Geol. Surv., Prof. Paper 181, p. 39, pl. 15, fig. 14–



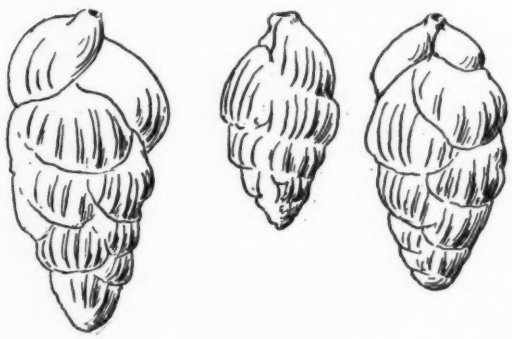
TEXT-FIG. *53—Euuvigerina yazooensis* (Cushman). Three tests from locality 5, ×65; two terminal views showing toothplates, ×180.



TEXT-FIG. *54—Euuvigerina cocoaensis* (Cushman). (*a,b,c,d*) specimens from unit 8; (*e*) topotype from Alabama. All ×65.

16; 1946, Cushman Lab. Foram. Res., Spec. Pub. 16, p. 29, pl. 5, fig. 22.

This species was found in abundance at locality 8 and is identical with specimens from the Eocene Cocoa sands of Alabama. It differs from *E. yazooensis* (Cushman) in the larger number of costae; however, these costae are not so prominent and never end in blunt spines. The toothplate is somewhat like that of *E. yazooensis*.



TEXT-FIG. *55—Euuvigerina cookei* (Cushman). Specimens from unit 8, ×80.

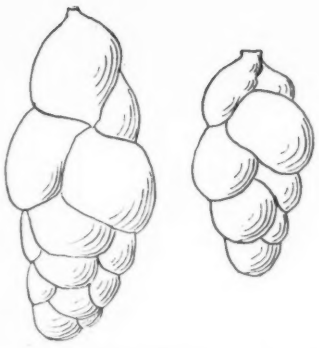
Genus NEOUVIGERINA Thalmann, 1952

NEOUVIGERINA MANTAENSIS (Cushman & Edwards)

Text-fig. 56

Uvigerina mantaensis CUSHMAN & EDWARDS, 1938, Cushman Lab. Foram. Res., Contr. vol. 14, p. 84, pl. 14, fig. 8; CUSHMAN & STONE, 1947, ibid., Spec. Pub. 20, p. 17, pl. 2, fig. 26; CUSHMAN & STAINFORTH, 1951, Jour. Paleont. vol. 25, p. 155, pl. 26, fig. 59.

This species was found in abundance at localities 5a and 6. It seems to belong to *Neouvigerina*, though the toothplates could not be observed. Its general form is that of *Neouvigerina chirana* Cushman & Stone with a smooth test, and the presence of pores on the neck indicates a reference to the genus *Neouvigerina*.



TEXT-FIG. 56—*Neouvigerina mantaensis* (Cushman & Edwards). Two tests from locality 6, ×65.

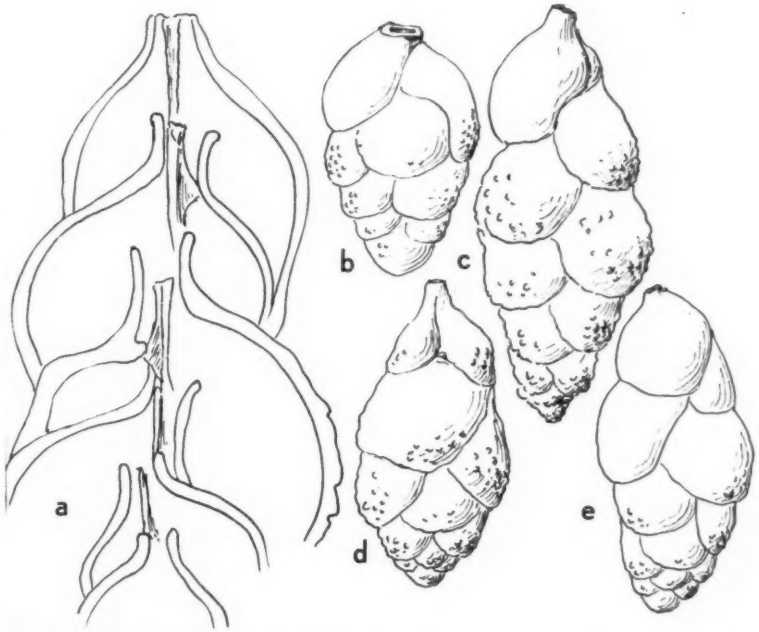
NEOUVIGERINA CHIRANA (Cushman & Stone)
Text-fig. 57

Uvigerina chirana CUSHMAN & STONE, 1947, Cushman Lab. Foram. Res., Spec. Pub. 20, p. 17, pl. 2, fig. 25; CUSHMAN & STAINFORTH, 1951, Jour. Paleont. vol. 25, p. 155, pl. 26, fig. 60.

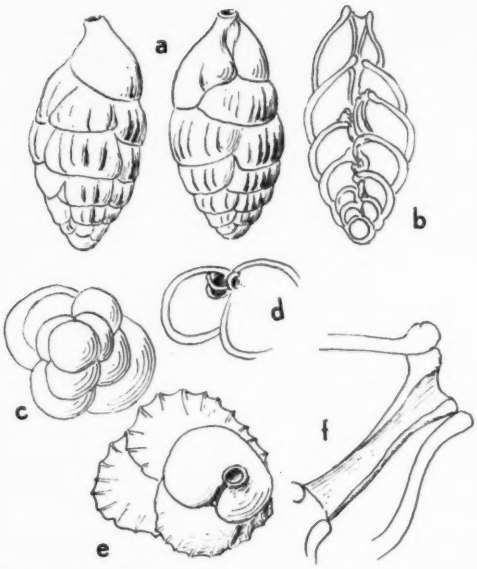
This species is plentiful at localities 5a, 6 and 7, and also present at locality 10. The ornamentation of blunt spines at the base of each chamber is typical and suggests a species intermediate between *N. mantaensis* Cushman & Edwards and the Oligocene *N. rustica* Cushman & Edwards. In *N. chirana* the axial wall of the last formed chamber shows a toothplate-suture which is a feature more of *Euuvigerina* and *Aluvigerina* than the modern species of *Neouvigerina*. Moreover the toothplate is not attached to the upper border of the foramen, but to its inner side. However, the toothplate does show the reduced character of *Neouvigerina*, forming only a thin straight plate running from one foramen to the next.

Genus ANGULOGERINA Cushman, 1927
ANGULOGERINA ECUADORENSIS Hofker, n. sp.
Text-fig. 58

Test small, fusiform, tapering towards both ends. Chambers slightly inflated with sutures distinct and depressed. Basal sutures of the chambers horizontal. Initial end smoothly rounded in megalospheric form, somewhat more pointed in microspheric form. Greatest breadth about the middle of



TEXT-FIG. 57—*Neouvigerina chirana* (Cushman & Stone). (*a*) longitudinal section showing toothplates, ×180; (*b,c*) test from Locality 7; (*d*) test from unit 10; (*e*) test from unit 6. *b–e*, ×65.



TEXT-FIG. *58*—*Angulogerina ecuadorensis*, n. sp. (*a*) two views of the holotype; (*b*) longitudinal section; (*c*) initial chambers; (*d*) transverse section showing toothplate; (*e*) apertural view; (*f*) toothplate in last formed chamber. *a,d*, ×80: *b,c,e* ×180: *f* ×240.

the test. Last chamber with only a very short neck, which shows a suture on the axial side, ending in a rounded aperture with inconspicuous phyaline border, the neck always slightly bent towards the axis. Whole test, except for last formed chambers, ornamented with very fine, narrow costae, up to eight on a chamber. Pores very fine.

Test triserial throughout. Initial chamber globular without a neck. Apertures in next four rows strongly bent towards the axis, sutural or nearly so, thus suggesting bulimine apertures. Necks only formed on the last formed chambers, in which the toothplate accordingly becomes free from the inner wall. The toothplate is a narrow plate running straight through the chamber in the final whorls, with both sides slightly bent. Length up to 0.50 mm., breadth 0.25 mm.

Through the transverse section is rounded this species shows the features of primitive *Angulogerina*, such as the Oligocene *Angulogerina oligocenica* and *"Uvigerina" gardnerae* Cushman. The toothplate and lack of a neck in the early chambers, also the suture at the inner side of the last chamber, are angulogerine features. The species was not mentioned by Cushman & Stainforth, though it is common in unit 12.

Type locality.—Outcrops of tuffaceous shale on Cerro de Hoja, about 15 km. east of Portoviejo, Ecuador. Type level: San Mateo formation, Upper Eocene. Type specimens deposited in the Cushman Collection, U. S. National Museum, P4907 (6 syntypes).

Family CASSIDULINIDAE
Genus CASSIDULINA d'Orbigny, 1826

Cushman & Stainforth mentioned two species of *Cassidulina* from the Eocene of Ecuador but their determinations must be modified. They described *Cassidulina globosa* Hantken as "common at Locality 6", but the species common at locality 6 is quite different from topotypes of that species. *C. globosa*, common at many European localities of Lower Oligocene, always shows an opaque test with extremely fine pores (pore index 65—0.3, ×500), whereas the Ecuador species has a hyaline test with more distinct pores (14/20—0.5, ×500). Moreover the aperture is the species from locality 6 is much more obliquely placed than in *C. globosa* Hantken. It much more resembles *C. subglobosa* Brady, though it seems to be slightly different and is referred below to *C.* cf. *subglobosa* Brady.

Typical *Cassidulina globosa* Hantken does occur in the Eocene of Ecuador. Specimens in no way different from the European species were found at localities 5, 7 and 12; though never common. The same form occurs in the Chira shale of Peru and was correctly determined by Cushman & Stone.

A third species occurring at localities 6 and 12, but always relatively rare, seems to be the form mentioned by Cushman & Stainforth as *Cassidulina* cf. *C. crassa* d'Orbigny, but it actually differs greatly from that species. It shows narrow chambers with the sutures parallel to one another, a very long and narrow aperture, a compressed test, and very slightly inflated chambers. The wall is always very opaque and the pores are distinct and widely spread (8—0.5, ×500). True *C. crassa* from the Eocene Chira shale of Peru is twice as large with the typical broad and inflated cham-

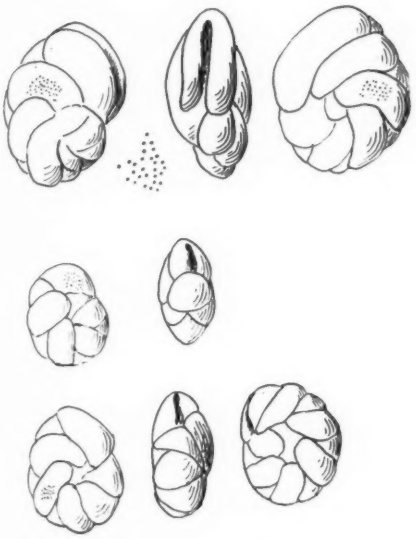
bers, and very fine, closely-spaced pores (40—0.5, ×500). The Ecuador species is here re-named *Cassidulina sublaevigata*, n. sp., since its shows certain characteristics of *C. laevigata* d'Orbigny.

Characteristic specimens of *C. crassa* were tentatively, but correctly, recognized in the Chira shale by Cushman & Stone, and a few identical specimens were found in Ecuador at locality 6.

CASSIDULINA SUBLAEVIGATA Hofker, n. sp.
Text-fig. 59

Cassidulina cf. *crassa* CUSHMAN & STAINFORTH, 1951, Jour. Paleont., vol. 25, p. 160.

Test small, length from 0.18 to 0.36 mm., thickness from 0.10 to 0.18 mm. Chambers with sutures curved backward, two to three times as long as broad. Pores distinct



TEXT-FIG. 59—*Cassidulina sublaevigata*, n. sp. Upper row, a specimen from unit 6, ×65; inset, portes ×180. Below, two cotypes from locality 12, ×65.

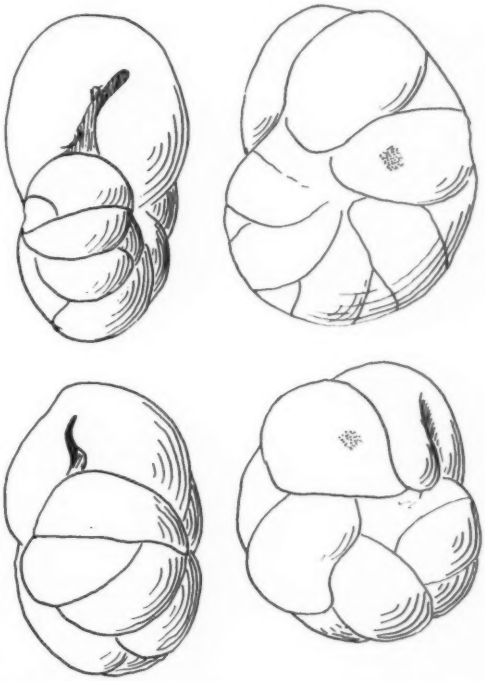
but fine, wall opaque. Aperture a long narrow slit, straight to slightly oblique. Five to six chambers on each side in the last formed whorl. Pore-index 8—0.5, ×500. Found at localites 6 and 12, never common.

Type locality.—Outcrops of tuffaceous shale on Cerro de Hoja, about 15 km. west of Portoviejo, near Manta, Ecuador. Type Level: San Mateo formation, Upper Eocene. Type specimens have been deposited in the Cushman Collection, U. S. National Museum, P4908 (holotype) and P4809 (paratypes).

CASSIDULINA CRASSA d'Orbigny
Text-fig. 60

Cassidulina crassa D'ORBIGNY, 1839, Voyage dans l'Amérique Méridionale; Foraminifères, tome 5, pt. 5, p. 56, p. 7, fig. 18–20.
Cassidulina cf. *crassa* CUSHMAN & STONE, 1947, Cushman Lab. Foram. Res., Spec. Pub. 20, p. 24.

Test large for the genus, length up to 0.60 mm., thickness about 0.30 mm. Sutures rounded, greatest breadth of each chamber near the middle, chambers slightly inflated. Pores very fine, pore-index 40—0.5, ×500. Wall opaque. Aperture loop-shaped, narrow, elongate, oblique and curved. Five to six pairs of chambers in each whorl. Rare at locality 6.

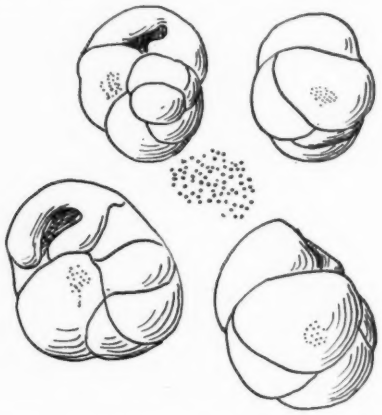


TEXT-FIG. 60—*Cassidulina crassa* d'Orbigny. Upper row, a specimen from unit 6, Ecuador: lower row, a specimen from the Chira shale of Peru. All ×80.

CASSIDULINA cf. C. SUBGLOBOSA
Brady
Text-fig. 61

Cassidulina globosa CUSHMAN & STAINFORTH (not Hantken), 1951, Jour. Paleont., vol. 25, p. 160.

Test small, length up to 0.25 mm., thickness up to 0.20 mm., subglobular in shape. Chambers arranged in an irregularly biserial whorl; last formed chambers enlarge rapidly.



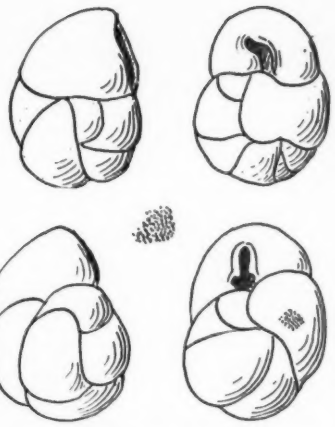
TEXT-FIG. *61—Cassidulina* cf. *C. subglobosa* Brady. Two specimens from unit 6, ×80. Inset shows pores, ×235.

Sutures rounded, chambers inflated. Wall always hyaline, with fine but very distinct pores. Pore index 14/20—0.5, ×500. Aperture loop-shaped, very oblique, in the slightly flattened apertural face. Common at locality 6.

CASSIDULINA GLOBOSA Hantken
Text-fig. 62

Cassidulina globosa HANTKEN, 1875, K. Ungar. Geol. Anst., Mitt. Jahrb., Bd. 4, Heft 1, p. 64, pl. 16, fig. 2; CUSHMAN & STONE, 1947, Cushman Lab. Foram. Res., Spec. Pub. 20, p. 23, pl. 3, fig. 8.

Test small but somewhat larger than in *C.* cf. *C. subglobosa*, length up to 0.35 mm., thickness 0.24 mm. Chambers, somewhat inflated in an irregular double whorl with rounded and twisted sutures. Walls very opaque, with extremely fine, densely spaced pores. Pore-index 65—0, ×500. Apertural face flattened, aperture loop-shaped, at right-angles to the suture, straight or slightly curved, medium wide. Rare in units 5 and 7.



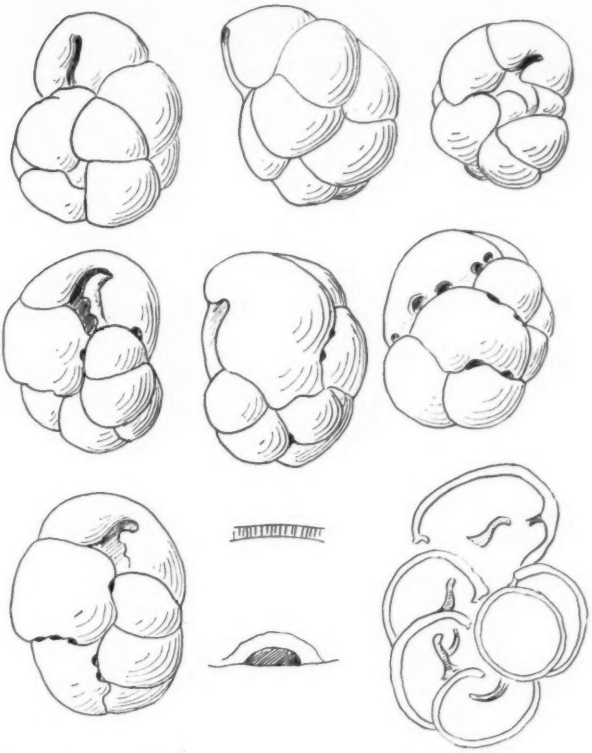
TEXT-FIG. *62—Cassidulina globosa* Hantken. Upper row, specimen from unit 7, lower row specimen from locality 5, both ×80. Inset, pores ×235.

Genus STICHOCASSIDULINA Stone, 1946
STICHOCASSIDULINA THALMANNI Stone
Text-fig. 63

Stichocassidulina thalmanni STONE, 1946: (see CUSHMAN & STAINFORTH, 1951, Jour. Paleont., vol. 25, p. 160.

This species was found at localities 5 and 7 and was compared with topotypes from the Eocene Chira shale of Peru, kindly supplied by Dr. P. J. Bermudez. The opaque, shining test has very fine pores in transverse sections. The last chamber has a broad apertural face in which an oblique loop-shaped aperture is partly covered by a slightly protruding toothplate. This toothplate is a simple one, with attached part creeping along the basal wall of each chamber and its free folded part partly blocking the aperture. Its free border is lobulate and partly covers the aperture. The supplementary openings in the walls along the sutures open into the lumen of the chambers, with no toothplates; they are quite similar to those of *Virgulinella*, also belonging to the Cassidulinidae. The specimens studied begin with a very large proloculus, visible as the chamber just below the apertural face. The later chambers form a double row, somewhat irregularly arranged due to their rapid enlargement.

The opaque walls, the fine pores, the oblique, loop-shaped aperture, the biserial arrangement of chambers, and the type of toothplate all point without doubt to the



TEXT-FIG. *63*—*Stichocassidulina thalmanni* Stone. Upper row, specimens from unit 5a, ×65. The place of this form is somewhat doubtful, since real sutural openings are not apparent. Middle row, three specimens from the Chira shale of Peru, ×30. Bottom row, a specimen from Peru, ×30; a section of the wall to show the very fine pores, ×180; a sutural opening, ×180; section through a Peruvian specimen to show tht toothplates in the chambers, ×30.

Cassidulinidae. The forming of supplementary openings along the sutures is also found in other Cassidulinidae, e.g., *Virgulinella* and *Candeina*. A conspicuous feature is the large proloculus with a diameter of about 300μ. Small specimens from locality 5a show a smaller proloculus and no sutural openings could be traced; they may represent a poorly developed form or a different species.

Family NUMMULITIDAE
Genus NUMMULITES Lamarck, 1801
NUMMULITES HYALINA Hofker, n. sp.
Text-fig. 64,65

At localities 8 and 10 a typical *Nummulites* [—*Camerina*] occurs, not mentioned by Cushman & Stainforth. Its test is small for the genus, with diameter up to 0.70 mm. but mostly about 0.50 mm. (the smaller megalospheric form). The margin is mostly sharp and the thickness of the tests about 0.25 to 0.30 mm. The sutures are slightly raised or flush with the surface, very hyaline and distinct, running nearly radially out from the center, which in some cases shows a small, flattened umbilical knob. Near to the margin the sutures are curved backwards. The number of chambers in the last whorl is 14 or less.

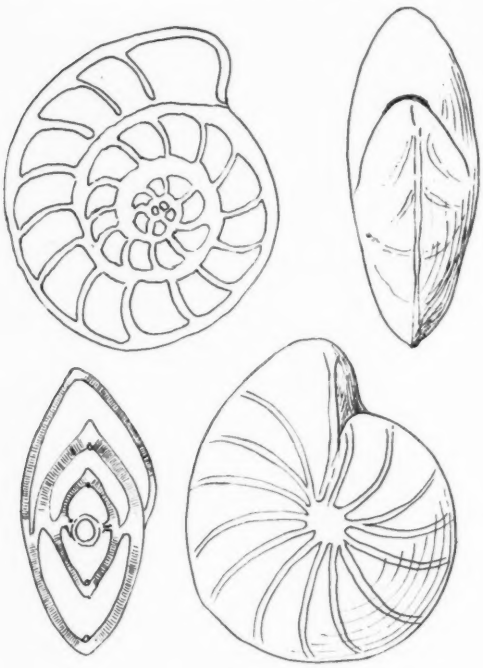
In transverse section a marginal canal is found running near to the lumen of the chambers, or even protruding slightly into the chambers. No marginal chord canals are developed. Two spiral canals run through the bases of the chambers in the calcite filling of the umbilical area. The pores are extremely fine and are lacking at the margin. Longitudinal sections reveal simple septal walls.

This primitive *Nummulites* is strongly reminiscent of "*Amphistegina*" *fleuriausi*

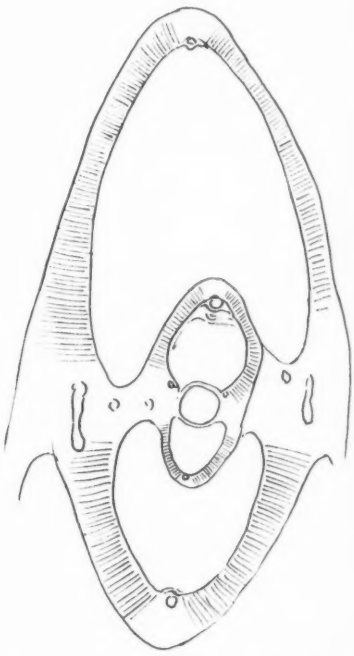
d'Orbigny from the Maestrichtian of Holland, which differs in its stronger development of an umbilical calcite knob. The simple canal system is quite similar.

There is much confusion about the taxonomy of the Nummulitidae. Many species have been put in the genus *Operculina* which cannot belong. The writer (Hofker, 1927), in discussing the finer structure of *Operculina complanata* (Defrance) and *Heterostegina*, has pointed out that in these forms a well-developed marginal chord canal system is found, together with the simple type of marginal canal found in *Nummulites*. Since *Operculina complanata* is the genotype of *Operculina* and shows a well-developed marginal chord system, it seems that this character should be stressed as the main feature dividing the genera *Operculina*, *Heterostegina* and *Cycloclypeus* from the genus *Nummulites*. On this basis Reuss (1862) and Visser (1951) were in error in transferring *Amphistegina fleuriausi* d'Orbigny to *Operculina*, because it has only the simple canal system of the genus *Nummulites* (see Hofker 1951). The higher forms of *Nummulites* may develop septal and basal canals, but never a marginal chord system.

Operculina seems to be restricted to the Upper Tertiary. Species recorded as *Operculina* from the Cretaceous and Eocene need to be re-studied as regards their marginal canal systems, but in the author's experience they always possess a simple system and belong to *Nummulites*. The new species from the Eocene of Ecuador is a simple one with no traces of double septal walls or septal canals.



TEXT-FIG. *64*—*Nummulites hyalina*, n. sp. Left, equatorial and vertical sections, ×65. Right, holotype from locality 10, ×65.



TEXT-FIG. *65*—*Nummulites hyalina*, n. sp. Vertical section of specimen from locality 8, ×180, showing the fine pores, the typical marginal canal with no trace of a marginal chord system, and the umbilical canals(?).

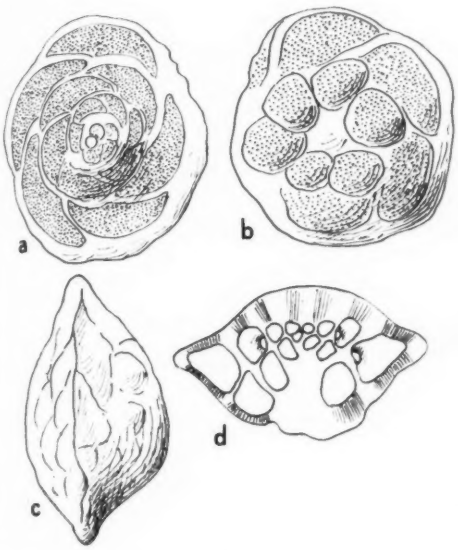
Type locality.—Shale exposures near Data at the southwest tip of the Guayaquil estuary, Ecuador. Type level: "Data beds," Upper Eocene. Type specimens have been placed in the Cushman Collection, U. S. National Museum, P4810 (20 syntypes).

Family AMPHISTEGINIDAE
Genus ASTERIGERINOIDES Bermudez, 1952

ASTERIGERINOIDES CRASSAFORMIS (Cushman & Siegfus)
Text-fig. 66

Astigerina crassaformis CUSHMAN & SIEGFUS, 1935, Cushman Lab. Foram. Res., Contr. vol. 11, p. 94, pl. 14, fig. 10; CUSHMAN & STAINFORTH, 1951, Jour. Paleont., vol. 25, p. 159, pl. 27, fig. 34,35.

Dorsal side only slightly convex; margin acute with a distinct, poreless keel; ventral side strongly convex, about twice as high as dorsal side. At dorsal side all chambers visible but covered at the center with a thick calcite layer; sutures strongly bent backwards; chambers narrow, elongate, about five in a whorl. At the ventral side the chambers of the last whorl are long, higher than at the dorsal side, sutures oblique. The supplementary chambers are roughly circular, leaving a clear central space which is filled with clear calcite. Transverse sections show the oblique toothplates and the small round septal foramina in the main chambers. The supplementary chambers are rounded in section and nearly as large as the main chambers. The pores are fine.



TEXT-FIG. 66—*Asterigerinoides crassaformis* (Cushman & Siegfus). Three external aspects, and a section showing the toothplates dividing the chambers from the chamberlets, with septal foramina only in the chambers. All ×65.

The total lack of ventral knobs near the aperture, the rounded supplementary chambers, and the large calcite boss on the ventral side indicate a relationship with the genotype of *Asterigerinoides;* but other characters point to *Asterigerina bartonensis* or *A. campanella* (Gümbel) of the European Eocene.

Family CIBICIDIDAE

The genotype of *Cibicides* is *Cibicides refulgens* Montfort. Only species with characters similar to that species should be included in this genus. These characters are: trochoidal, dorsal side flattened and attached, ventral side more or less inflated with more or less involute chambers; pores coarse and spare on both sides; wall microgranular, granulate in polarized light, with fine arenaceous grains embedded in the shell-substance, more or less opaque but never hyaline; aperture a curved slit at the margin, with raised border, often extending back along the spiral suture on the dorsal side, and in the older chambers often enclosed by porous plates.

The geologically oldest species are typically arenaceous with coarse pores, indicating a possible derivation from the Valvulinidae. Maestrichtian species have the wall already microgranular but also distinctly arenaceous. To this genus belong *Cibicides refulgens* Montfort, *C. excavatus* Brotzen, *C. convexus* (Reuss), *C. beaumontianus* (d'Orbigny), *C. lobatulus* (Walker & Jacob), and many allied forms.

All these species show simple septal walls which make them readily distinguishable from the *Gavelinella* group. They are more liable to confusion with the *Osangularia* group, but there are significant differences, as discussed under the family Darrelloididae

True Cibicididae are scarce in the Eocene of Ecuador. Cushman & Stainforth recorded nine species of *Cibicides* (1951, p. 162, 163), but actually the three commonest belong to other genera. The scarce forms appear to include true *Cibicides*, in particular *C.* cf. *C. lobatulus* (Walker & Jacob).

Family PARRELLOIDIDAE Hofker, new family

The genera of this family are trochoidally coiled, with all chambers visible at the dorsal side, usually only those of the last formed whorl visible on the ventral side. Exceptionally, for example *Planulina*, the ventral side may become evolute, but there is never a hollow umbilicus. In *Osangularia* pores are fine and present only on the dorsal side; in *Parrelloides* n. gen., *Siphonina*, etc. the pores are coarser, mainly on the dorsal side. The aperture is at the ventral suture, an opening of variable shape, mostly with a protruding upper border or lip. The chamber walls are almost invariably and distinctly hyaline.

The Parrelloididae differ from the Cibicididae in usually being inflated dorsally as well as ventrally; in having pores only or mainly on the dorsal side; in their more open aperture, which never extends back along the spiral suture; and in their hyaline, not opaque, walls. They differ from the Gavelinellidae in their simple, not double, septal walls, and in the absence of umbilici and umbilical foramina.

Genus PARRELLOIDES Hofker, n. gen.

Synonymy: *Cibicides* auct. [non Montfort, 1808]

Genotype: *Cibicides hyalinus* Hofker, 1951.

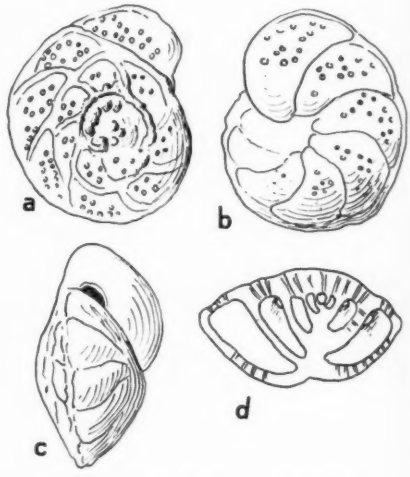
Description.—Test trochoid with dorsal and ventral sides both inflated; all chambers visible on the dorsal side, only those of the last whorl visible on the ventral side; pores on the dorsal side, but none on the ventral side except for scattered ones on the last chambers; aperture at the ventral suture near the margin, sometimes bending slighly over the margin but never extending back into the spiral suture; walls hyaline; septal walls simple.

Parrelloides, n. gen., is closely related to *Planulina* d'Orbigny, but differs in its inflated, uncompressed habitus, and in its completely involute ventral side.

PARRELLOIDES COOKEI (Cushman & Garrett)
Text-fig. 67

Cibicides cookei CUSHMAN & GARRETT, 1938, Cushman Lab. Foram. Res., Contr., vol. 14, p. 65, pl. 11, fig. 3; CUSHMAN & STAINFORTH, 1951, Jour. Paleont., vol. 25, p. 163, pl. 28, figs. 20,21,25.

This species is common at locality 6. The coarsely porous dorsal face is divided into chambers by thick sutures which in the center coalesce into irregular calcite bosses. The margin is sharp and poreless. Coarse



TEXT-FIG. 67—*Parrelloides cookei* (Cushman & Garrett). (*a*) dorsal side; (*b*) ventral side showing pores only in the younger chambers; (*c*) apertural view; (*d*) section showing septal foramina. All ×65.

pores are present on the ventral side also, but only towards the margin on the last three or four chambers. The aperture is a curved slit at the ventral suture, near the margin. Transverse sections show another typical feature of *Parrelloides*, the absence of a central knob on the ventral side. *P. cookei* is closely related to such Recent species as *Cibicides hyalinus* Hofker, *C. ungerianus* (d'Orbigny), *C. mundulus* (Brady, Parker & Jones) and *C. wuellerstorffi* (Schwager), all of which should be allocated to *Parrelloides*.

Genus OSANGULARIA Brotzen, 1940

This genus was known for some years as *Parrella* Finlay, 1939, but Brotzen's latter name was reinstated when *Parrella* Finlay was shown to be pre-occupied by *Parrella* Ginsburg, 1938, a genus of fishes (see

Thalmann & Graham, Cushman Found. Foram. Res., Contr., vol. 3, p. 31, 32, 1952).

Tests lenticular, often with keeled margin. At dorsal side all chambers visible, at ventral side only those of the last formed whorl. No umbilical cavity at ventral side. Sutures on the dorsal side always strongly oblique, but not those of ventral side. Pores only on the dorsal side, usually very fine. Walls always opaque, often yellowish. Aperture very distinctive, a sutural slit combined in various manners with a transverse opening. Remains of toothplates visible inside the chambers.

OSANGULARIA MEXICANA (Cole)
Text-fig. 68, 69

Truncatulina culter PLUMMMER, 1926, Univ. Texas Bull., no. 2644, p. 147, pl. 10, fig. 1; pl. 15, fig. 2.

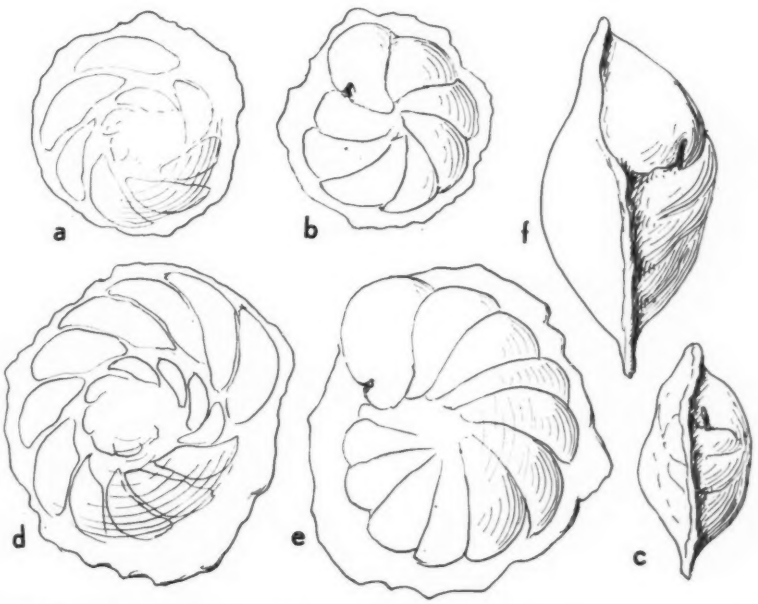
Pulvinulinella culter var. *mexicana* COLE, 1927, Bull. Am. Paleont., vol. 14, no. 51, p. 31, pl. 1, fig. 15,16.

Osangularia plummerae BROTZEN, 1940, Sver. Geol. Unders., Avh., ser. C, no. 435 (årsb. 34, no. 5), p. 30.

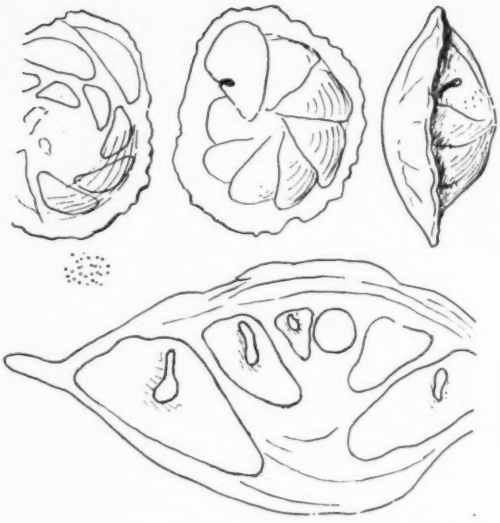
Parrella cf. *mexicana* CUSHMAN & STAINFORTH, 1951, Jour. Paleont., vol. 25, p. 159.

Several specimens were found at locality 7, and Cushman & Stainforth recorded a single specimen at locality 6. The dorsal side is always slightly convex, the ventral side strongly convex. The broad keel is typical. The central dorsal part is covered by thick layers of secondary calcite. The ventral sutures are curved and usually oblique. There are eight to ten chambers in the final whorl. The aperture consists of two parts, usually not connected, a very narrow sutural foramen and an areal foramen aligned at about 90° to the suture. Fine protopores are found only on the dorsal side; the ventral side is totally poreless. The specimens do not exceed 1 mm. in diameter, megalospheric specimens being smaller, with only seven to eight chambers in the last formed whorl.

This species is widely distributed in the Caribbean region and in Europe, especially in the Upper Eocene. A dorsal-to-ventral height ratio of 0.88:1, and an angle of about 90° between the two apertural elements are constant features in all the examples studied, including some from the Ypresian of Holland.



TEXT-FIG. 68—*Osangularia mexicana* (Cole). (*a,b,c*) megalospheric specimen; (*d,e,f*) microspheric specimen. Both from locality 7, ×65.



TEXT-FIG. *69—Osangularia mexicana* (Cole). From the Eocene of Holland. Upper row, three views of a specimen, ×65; below, vertical section showing septal foramina, ×180; inset, pores on the dorsal side, ×180.

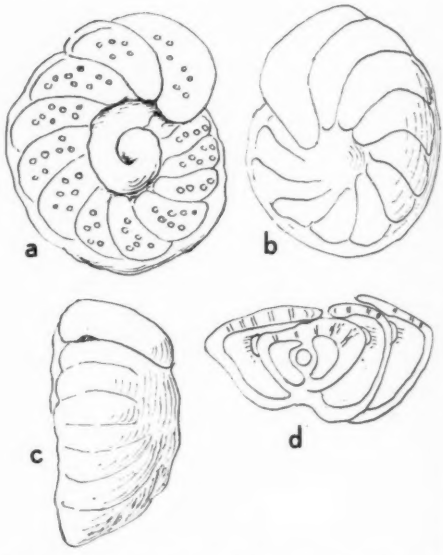
Family ANOMALINIDAE
Genus ANOMALINOIDES Brotzen, 1942
ANOMALINOIDES ACUTA (Plummer)
Text-fig. 70

Anomalina ammonoides var. *acuta* PLUMMER, 1926, Univ. Texas Bull. 2644, p. 149, pl. 10, fig. 2.
Anomalina acuta GLAESSNER, 1937, Moscow Univ., Paleo. Lab., Prob. Pal., vol. 2–3, p. 386, pl. 5, fig. 39.
Anomalinoides acuta BROTZEN, 1948, Sver. Geol. Unders., Avh., ser. C, no. 493, p. 87, pl. 14, fig. 2.

This species is common at locality 2. It was not listed by Cushman & Stainforth.

Test biconvex, but more so at the dorsal side, the ventral side being often nearly flat. No pores visible on the dorsal side ventral side very coarsely porous. In dorsal view the chambers nearly reach the center, leaving only a small, but distinct, open area, which in many cases is slightly depressed; dorsal sutures curved, slightly depressed or flush, not ornamented. In ventral view only the chambers of the last formed whorl are visible, as on the dorsal side, but are distinctly separated from the center, which is marked by a prominent helicoid depression. The ventral sutures are also curved backwards. The margin is slightly acute and hyaline. The septal foramina are interio-marginal and very narrow umbilical slits are visible at the ventral side. Length 0.54 mm., thickness 0.27 mm.

All these characters suggest a close relationship to the Gavelinellidae, but the septal walls are not double and Brotzen's allocation of the species to *Anomalinoides* is



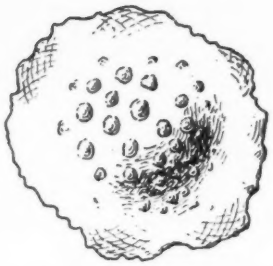
TEXT-FIG. *70—Anomalinoides acuta* (Plummer). (*a*) ventral side (*b*) dorsal side: (*c*) peripheral view; (*d*) section in which the nearly open umbilical apertures can be seen at the ventral side (above), whereas the septal foramina are marginally placed. Pores only in the ventral walls. All ×65.

accepted. The Ecuador specimens are identical with topotypes from the Midway of Texas. The Stockletten marls of Bavaria, usually considered Lower Eocene, carry a fauna very similar to the Paleocene unit 2 of Ecuador, including *Anomalinoides acutus*.

Family TINOPORIDAE
Genus LEPIDOCYCLINA Gümbel, 1870
LEPIDOCYCLINA ECUADORENSIS Hofker, n. sp.
Text-fig. 71–73

Lepidocyclina peruviana Cushman var. VAUGHAN, 1937: *in* SHEPPARD, Geology of Southwestern Ecuador, p. 170. pl. 117, fig. 4.

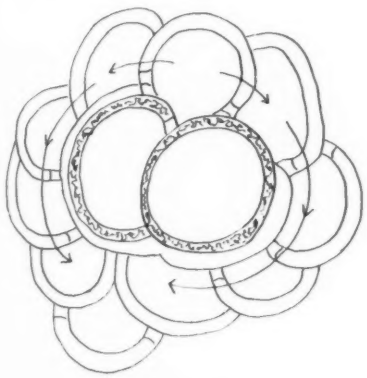
Test small, never more than 1.5 mm. in diameter, lenticular. Several distinct pillars



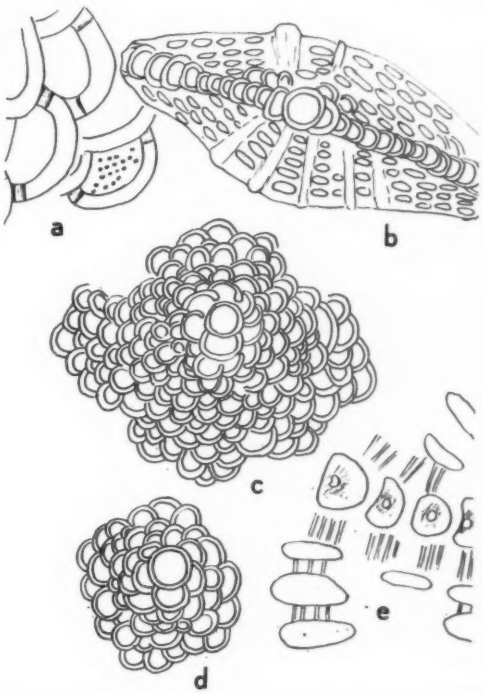
TEXT-FIG. 71—*Lepidocyclina ecuadorensis*, n. sp. Holotype from locality 4, external view ×20.

in the central part, always more at one side than at the other. Chambers at surface small, in a honeycomb pattern between the pillars but becoming arcuate near the margin. In horizontal section all the median chambers are arcuate. The megalospheric proloculus is relatively small (120−150μ) and totally globular; a second chamber, always smaller, is added to it at one side; the wall between these two chambers is no thinner than the wall of the proloculus and is always curved towards the second chamber. Two or more sets of nepionic chambers are formed, running in opposite directions. The median chambers always show two foramina at the base of each chamber; these foramina are rounded and in some cases show a small basal tooth. The lateral chambers are narrow and somewhat lenticular, and in vertical sections are seen arranged in straight rows normal to the surface, usually with a single row of chambers between any two adjacent pillars. Distinct pores are present in the lateral walls of the median chambers, connecting them with the lateral chambers. The lateral chambers also communicate by pores, but no connecting stolons could be traced.

This species differs from *L. peruviana* Cushman mainly in the shape of the protoconch with its totally globular initial chamber. In *L. peruviana* (also *L. douvillei* Lisson) the separating wall between the proloculus and second chamber is always straight and distinctly thinner than the wall of the proloculus. *L. ecuadorensis*, n. sp,



TEXT-FIG. 72—*Lepidocyclina ecuadorensis*, n. sp. Central part of equatorial section, ×180. The proloculus is divided from the second chamber by a curved wall, which shows that the two chambers were not formed simultaneously. There is a single primary auxiliary chamber, from which two coils of nepionic chambers have been formed. The two protoconch-chambers are backed by a secondary wall. This formation of central chambers is somewhat more primitive than that found in *L. peruviana*, in which two primary auxiliary chambers and four directions of growth are found.



TEXT-FIG. 73—*Lepidocyclina ecuadorensis*, n. sp. (*a*) median chambers, showing the foramina and pores in the lateral wall, ×180; (*b*) transverse section, ×30; (*c,d*) partial equatorial sections of megalospheric individuals, ×30; (*e*) part of a transverse section, showing the median chambers with foramina, and the lateral chambers with interconnecting pores, ×180.

moreover, has fewer layers of lateral chambers (never more than five in the center) than *L. peruviana*.

The shape of the megalospheric embryonic apparatus in *Lepidocyclina* is important. In this new species the thick, curved wall between them indicates that the proloculus was formed before the second chamber. In most known species, as in *L. peruviana*, these two chambers were formed simultaneously, since the septal wall between them is straight and very thin, indicating its formation within a mass of protoplasm and not at its outer surface. Hence *L. ecuadorensis* must be a primitive species, having a small monothalamous embryo whereas more advanced species show a larger and polythalamous embryo. In these more advanced forms the outer wall of the whole embryonic apparatus is frequently thickened, but in *L. ecuadorensis* this wall is hardly thickened at all.

Type locality.—Sea cliffs at Ancon in southwest Ecuador. Type level: the "Clay Pebble Beds," probably late Middle Eocene; common. Type specimens have been placed in the Cushman Collection, U. S. National Museum, P4811 (4 syntypes).

Family NONIONIDAE
Genera NONIONELLA Cushman, 1926 and NONION Montfort, 1808

In the genus *Nonionella* the chambers are always narrow, and they overlap strongly at both sides. The test is usually distinctly trochoid, though many species appear planispiral and are only trochoid in the hidden initial chambers. The pores are very fine and closely packed and the walls are always opaque, granulate in polarized light in all the species studied. In contrast true *Nonion* shows planispiral coiling from its initial stages, has hyaline walls, and shows negligible overlap of its chambers. Its pores are more distinct, though still fine. Thus *Nonion* and *Nonionella* can be separated without establishing the trochoid tendency of the latter. In both genera the septal walls are simple with no trace of a septal canal system: the aperture is a narrow slit at the base of the last formed chambers, mostly only at the margin and never extending to the umbilicus.

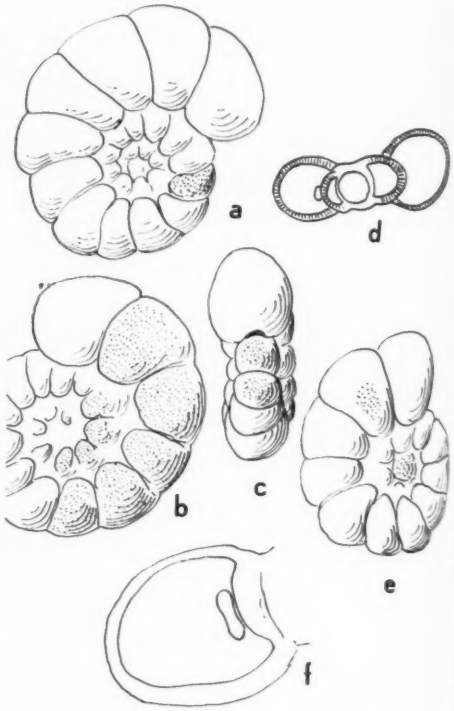
There are planispiral species with a wide apertural slit and an open umbilicus on each side, but all these species show umbilical foramina, double septal walls, and rather coarse pores. Though largely classified as *Nonion* by older authors, this group properly belongs in *Gavelinonion* Hofker of the Gavelinellidae [cf. *Gavelinonion chiranus* (Cushman & Stone) described below.]

NONION PERUVIANUS (Cushman & Stone)
Test-fig. 74

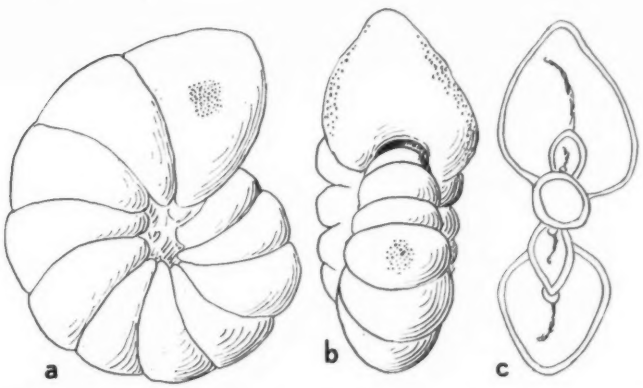
Planulina peruviana CUSHMAN & STONE, 1947, Cushman Lab. Foram. Res., Spec. Pub. 20, p. 26, pl. 4, fig. 6.

This species is abundant at locality 5a, but not mentioned by Cushman & Stainforth. The specimens have been compared with topotypes from the Eocene Chira shale of Peru and are identical.

All chambers are visible on both sides and



TEXT-FIG. 74—*Nonion peruvianus* (Cushman & Stone). (*a,b*) both sides of a test; (*c,d,e*) apertural view, cross-section, and external view of a smaller test. (*f*) part of a tangential section, showing the marginally placed septal foramen. All from locality 5a, *a–d*, ×65: *f*, ×180.



TEXT-FIG. 75—*Nonion brunatus*, nom. nov. Side and edge view of a specimen from locality 5a; (*c*) transverse section showing a regular structure in the lumen of each chamber, possibly remnants of toothplates. All ×65.

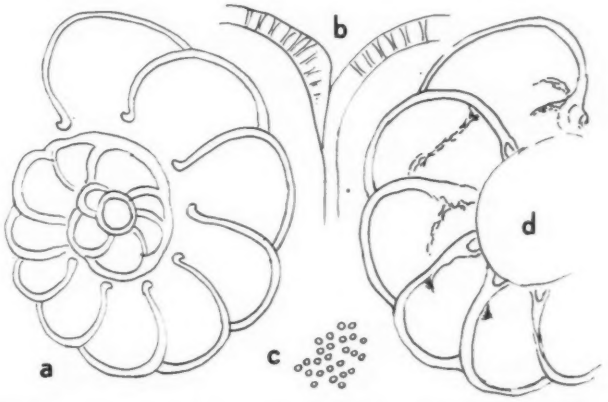
only overlap slightly in the last whorl. Each chamber is clearly visible, since the sutures are distinctly depressed. The walls are pierced by fine but distinct pores, found all over the walls on both sides. The test is completely planispiral. The aperture is a narrow slit sutural to the margin, symmetrically placed in respect to the axis of the test. The outer walls are yellowish and thin, the septal walls simple.

All these characters point to *Nonion* and not *Planulina*.

NONION BRUNATUS Hofker, nom. nov.
Text-fig. 75,76

Planulina chirana CUSHMAN & STONE, 1947, Cushman Lab. Foram. Res., Spec. Pub. 20, p. 26, pl. 4, fig. 3; CUSHMAN & STAINFORTH, 1951, Jour. Paleont., vol. 25, p. 162, pl. 28, fig. 13.

This species occurs abundantly in unit 5a. The tests are mostly compressed and deformed, but several well-preserved ones were compared with topotypes from the Peruvian Eocene Chira shale and are identical. The tests are always brownish colored with fine but distinct pores all over the walls. The test is planispiral and on both sides the last whorl of chambers completely envelops the earlier whorls. The apertural face is poreless, the aperture an arched slit at the margin. The sutures are depressed, the septal walls simple except in the sutural depressions. As in the previous



TEXT-FIG. 76—*Nonion brunatus*, nom. nov. From the Chira shale of Peru. (*a*) median section; (*d*) tangential section of same specimen showing regular structures in the chambers, possibly remnants of toothplates (cf. Fig. 73-c) and septal foramina in the chamber walls. Both ×65. (*b*) section of the wall at the suture, showing pores, ×240. (*c*) pores, ×180.

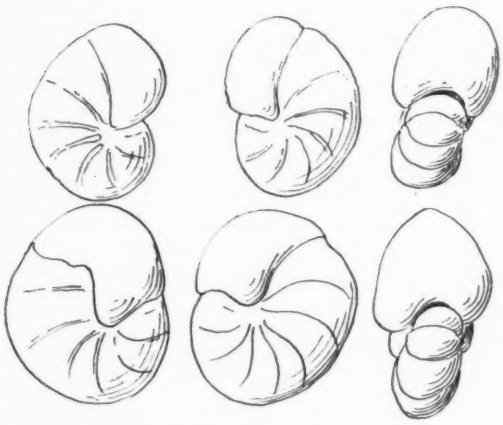
species, all these features point to *Nonion* and not to *Planulina*. However, *Nonion chiranus* is pre-occupied (by Cushman & Stone, 1947, p. 10, pl. 1, fig. 27) and even though this species is reallocated to *Gavelinonion*, its name is not available for the present species. The new name, *N. brunatus*, is therefore introduced.

Type specimens have been placed in the Cushman Collection, U. S. National Museum P4819.

NONIONELLA STAINFORTHI Hofker, nom. nov.
Text-fig. 77

Nonion ecuadoranum CUSHMAN & STAINFORTH, 1951, Jour. Paleont., vol. 25, p. 149, pl. 26, fig. 19,20.

This species is abundant at locality 5a. The chambers have the low habitus of *Nonionella*. Many specimens show a



TEXT-FIG. 77—*Nonionella stainforthi*, nom. nov. Views of two tests from locality 5a, ×65

slightly asymmetrical coiling of the last formed chambers. The pores are extremely fine and very closely packed, and the walls are opaque. Transverse sections also show typical features of *Nonionella*. The species must therefore be transferred from *Nonion* to *Nonionella*, but the name *Nonionella ecuadorana* is pre-occupied (by Cushman & Stevenson, 1948, Cushman Lab. Foram. Res., Contr., vol. 24, p. 54. pl. 9, fig. 15); it is here re-named *Nonionella stainforthi*.

Type specimens have been placed in the Cushman Collection, U. S. National Museum P4820.

Family VALVULINERIIDAE
Genus VALVULINERIA Cushman, 1926

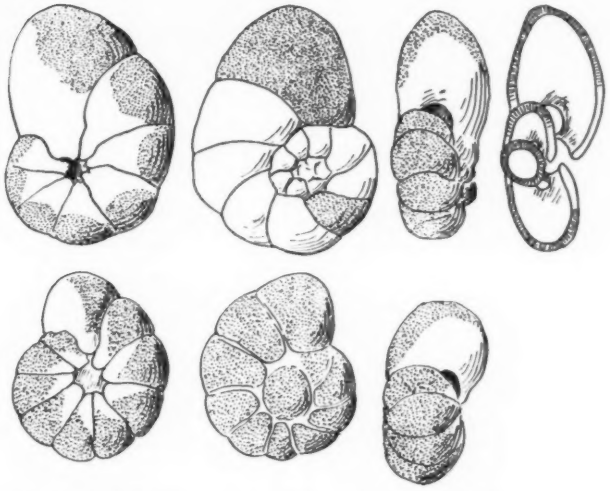
Based on the genotype, *Valvulineria californica* Cushman, the characteristics of this genus are: test more or less compressed with rounded margin; calcareous and usually hyaline, pores distinct but fine. Pores over the whole surface area, except for a smaller or larger area on the ventral side, namely the lip covering the umbilical part of the foramen. The foramen is divided into two parts, the septal foramen and the umbilical foramen; both parts may remain open, or the umbilical foramen may be closed in the initial chambers; often the foraminal lips cover part of the umbilical cavity. A very typical feature is the straight suture from umbilical lip towards the margin on the ventral side, never showing an indentation indicative of a protoforamen such as exists in many species of *Discopulvinulina*, *Hanzawaia* and *Streblus*.

VALVULINERIA STAINFORTHI Hofker, nom. nov.
Text-fig. 78

Discorbis samanica CUSHMAN & STONE, 1947, Cushman Lab. Foram. Res., Spec. Pub. 20, p. 19, pl. 2, fig. 27; CUSHMAN & STAINFORTH, 1951, Jour. Paleont., vol. 25, p. 157, pl. 27, fig. 14,15.

This species is common at locality 12. On the dorsal side all the chambers are visible, those of the last whorl tending to overlap the previous one; the sutures are slightly curved backwards, often somewhat thickened and limbate; the whole dorsal side is pierced by very fine, closely set pores. The margin is rounded and entirely covered by pores. On the ventral side only the chambers of the last formed whorl are visible, leaving a small umbilicus free; the ventral sutures are straight or slightly curved. A rather large part of the ventral surface is poreless and transverse sections reveal that this central poreless area consists of large umbilical lips over the open umbilical apertures. The main aperture is on the ventral side, an arched slit in the totally poreless apertural face. The arched septal foramina are not in contact with the umbilical openings.

All these features point to the genus



TEXT-FIG. 78—*Valvulineria stainforthi*, nom. nov. From locality 12. Upper row, views and a section of a single specimen. Lower row, views of a smaller specimen. All ×65.

Valvulineria, and away from the "*Discorbis*" group (*Conorboides*, *Discopulvinulina*, etc.) which always have a protoforamen carrying a toothplate.

Since *Valvulineria samanica* is preoccupied (by Cushman & Stone, *loc. cit.*, p. 19, pl. 3, fig. 1), this species is re-named as above.

VALVULINERIA SUBBADENENSIS (Pijpers)
Text-fig. 79

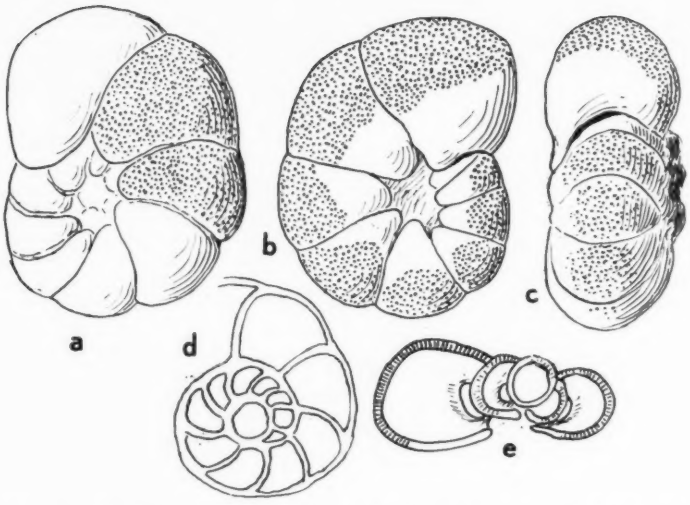
Anomalina subbadenensis PIJPERS, 1933, Geol. Pal. Bonaire, p. 72; CUSHMAN & STAINFORTH, 1951. Jour. Paleont., vol. 25, p. 162, pl. 28, fig. 18,19.

Many specimens occur at locality 8. They are variable in size and in the habitus of the test, suggesting that during life this was an attached species. On the dorsal side all chambers are usually seen, though there is a slight involute tendency and chambers of the earlier coils may be partly covered. The whole dorsal face is pierced by fine but distinct pores. The margin is strongly rounded and becomes lobulate in the later chambers; it is porous. The dorsal sutures are slightly curved back and mostly depressed, the early ones slightly limbate and thickened. On the ventral side only the chambers of the last formed whorl are visible, surrounding a fairly distinct umbilical area. On this side only the parts toward the margin are porous and a large central area is poreless. The umbilical area is distinctly depressed. The ventral sutures are straight and radial, slightly depressed. Vertical sections reveal that the septa are simple and thin. At the ventral suture of the last formed chamber the narrow slit aperture is visible, running down into the umbilical area. Sections show that the poreless ventral parts of the chambers are umbilical lips covering the umbilical apertures. The slitlike septal foramina are ventrally placed, but do not reach the umbilical area.

All these characteristics correspond to the genus *Valvulineria*. All tests have a yellowish color reminiscent of the Cretaceous valvulinerias known as *V. lenticula* (Reuss). Our specimens seem to agree with Pijper's species, but have nothing in common with *Anomalina*, a genus which never shows umbilical apertures.

Family ALABAMINIDAE
Genus GYROIDINOIDES Brotzen, 1942

Test always trochoid, with all chambers visible in dorsal aspect, usually only those of the last formed whorl visible in ventral view. Test always opaque, with fine, densely set pores in the walls, porous on both sides. Aperture a slit along the ventral suture extending into the umbilical cavity, which



TEXT-FIG. *79*—*Valvulineria subbadenensis* (Pijpers). (*a*) dorsal side; (*b*) ventral side; (*c*) apertural view; (*d*) horizontal section; (*e*) vertical section. From locality 5, all ×65.

is always open. The chamber walls bend into the umbilical cavity to cover the umbilical apertures, which open into the cavity and are never closed. The dorsal sutures are always nearly radial, but a turning-in of the dorsal part of the apertural face often leads to a distinct backward hook where the dorsal sutures meet the spiral suture. In many forms a distinct gutter forms along the spiral suture in the later stages.

In some species the dorsal whorls pile up conically. These forms have been placed in a separate genus, *Rotaliatina* Cushman, but in other respects they do not differ from normal *Gyroidinoides*, and intermediate forms exist, so that the validity of *Rotaliatina* is doubtful.

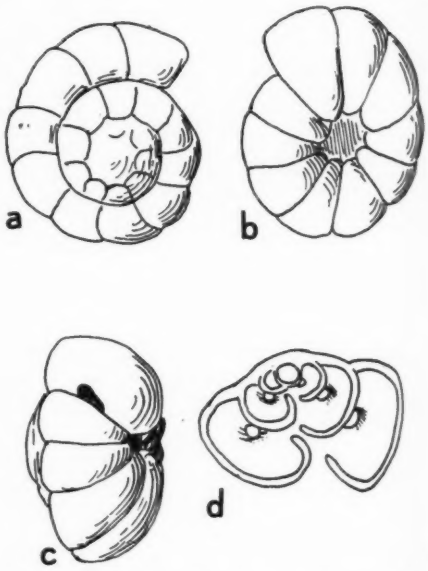
The genus *Gyroidina* includes those species in which the umbilical cavity is completely closed. At present only some Recent and sub-Recent species are known to possess this character.

Gyroidinoides seems to be related to *Valvulineria* and *Alabamina;* internal toothplates have never been found, not even in the oldest forms from the Lower Cretaceous.

GYROIDINOIDES CHIRANUS (Cushman & Stone)
Text-fig. 80

Gyroidina chirana CUSHMAN & STONE, 1947, Cushman Lab. Foram. Res., Spec. Pub. 20, p. 23, pl. 3, fig. 4; CUSHMAN & STAINFORTH, 1951, Jour. Paleont., vol. 25, p. 158, pl. 27, fig. 25.

This species occurs at locality 5. It is characterized by ten chambers in the last



TEXT-FIG. *80*—*Gyroidinoides chiranus* (Cushman & Stone). (*a*) dorsal side; (*b*) ventral side with umbilicus; (*c*) apertural view; (*d*) vertical section showing the small, rounded septal foramina. From locality 5, all ×80.

whorl, oblique ventral sides, slightly acute margin, lobulate outline due to the inflated chambers, and conspicuous umbilicus. The aperture is curved and more or less arched, not slitlike. Transverse sections reveal that the ventral walls are bent upward at the umbilicus, leaving open umbilical foramina. The species is a typical *Gyroidinoides*.

GYROIDINOIDES SCALATUS (Garrett)
Text-fig. 81

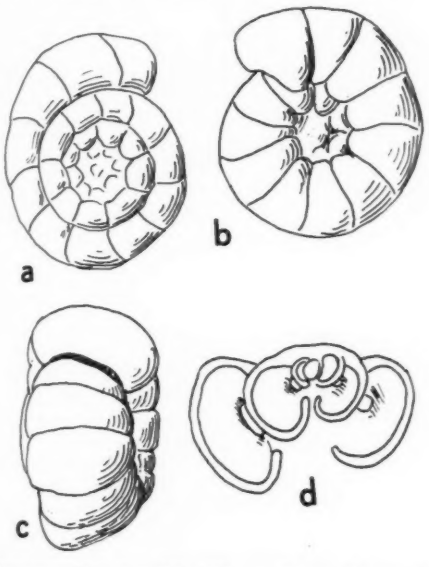
Gyroidina scalata GARRETT, 1938: see CUSHMAN & STAINFORTH, 1951, Jour. Paleont., vol. 25, p. 158, pl. 27, fig. 26,27.

This species is common at locality 6. There are eleven to twelve chambers in the last whorl; the dorsal sutures are curved and trend backward, contrary to *G. chirana* in which they are straight and radial. The outline is more rounded, less lobulate, and in side view the ventral chambers are more upright, less oblique, than in *G. chirana*. The umbilicus is very wide, with the earlier whorls plainly visible. The aperture is a narrow slit along the ventral suture. Transverse sections reveal strongly curved chamber-walls bending up in the umbilical region to form large umbilical openings. It is a typical *Gyroidinoides* and seems to be closely allied to *G. pontoni* Brotzen, of the European Upper Cretaceous.

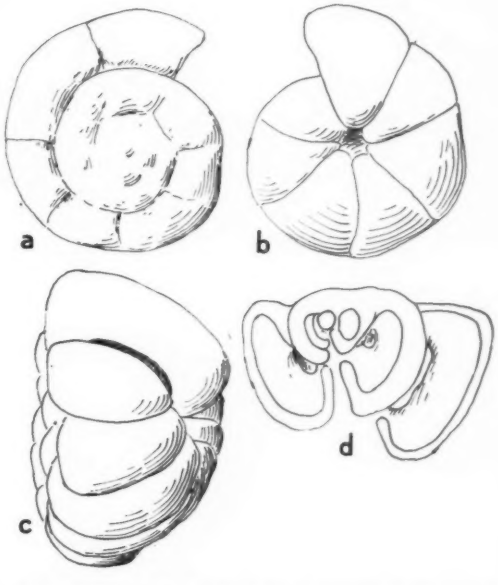
GYROIDINOIDES PLANATUS (Cushman)
Text-fig. 82

Gyroidina orbicularis var. *planata* CUSHMAN' 1935; see CUSHMAN & STONE, 1947, Cushman Lab. Foram. Res., Spec. Pub. 20, p. 22, pl. 3, fig. 5; CUSHMAN & STAINFORTH, 1951, Jour. Paleont., vol. 25, p. 158, pl. 27, fig. 22,23.

This species occurs at Locality 6. The relatively large test shows six to seven chambers on the dorsal side, separated by straight, radial, sunken sutures. The dorsal whorls are very narrow, the early ones not clearly visible from the outside since they are covered by a thick layer of calcite. There is a conspicuous gutter between the last formed whorl and the early ones. The dorsal side is nearly flat. The margin is rounded, not lobulate. The dorsal part of the apertural face is bent distinctly inwards. The high ventral chambers are separated by almost invisible sutures, flush with the surface. The umbilicus is narrow. Transverse sections show that the umbilicus is formed by strong, abrupt upward bending of the ventral chamber-walls, leaving a narrow



TEXT-FIG. *81—Gyroidinoides scalatus* (Garrett). (*a*) dorsal side; (*b*) ventral side showing the large umbilicus; (*c*) apertural view; (*d*) vertical section. From unit 6, all ×180.



TEXT-FIG. *82—Gyroidinoides planatus* (*Cushman*). (*a*) dorsal side; (*b*) ventral side; (*c*) apertural view; (*d*) vertical section showing septal and umbilical foramina. From unit 6, ×65.

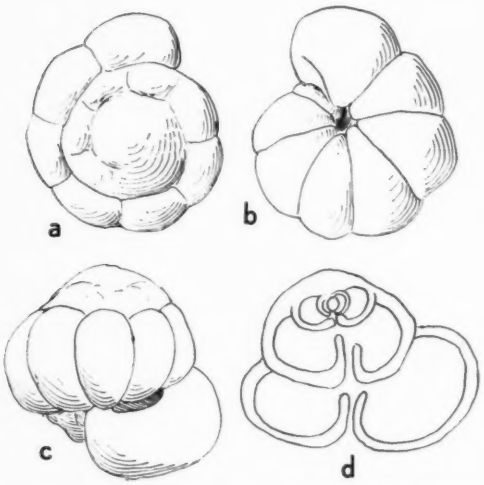
umbilical foramen free. Diameter 0.50 mm., height 0.36 mm.

Since *Gyroidina orbicularis* d'Orbigny is a true *Gyroidina* with totally closed umbilicus, and this form from the Upper Eocene of Ecuador, Peru and elsewhere is a typical *Gyroidinoides*, the original varietal designation cannot stand. It is necessary to separate *Gyroidinoides planatus* as a distinct species.

Genus ROTALIATINA Cushman, 1925
ROTALIATINA MEXICANA Cushman
Text. fig. 83

Rotaliatina mexicana CUSHMAN, 1924, Cushman Lab. Foram. Res., Contr., vol. 1, p. 4, pl. 1, fig. 1.

This species is rather common at locality 5, but is not mentioned by Cushman & Stainforth. On the dorsal side only the chambers of the narrow final whorl are clearly visible, the earlier part being covered by a thick, dome-shaped layer of secondary calcite. There are seven chambers in the last formed whorl, the final chamber showing slight inward bending of the apertural face, as in *Gyroidinoides*. Ventrally the sutures are slightly curved, radiating from the small open umbilicus. In side view the margin is seen to be strongly rounded, the chambers inflated. The broad apertural face on the last formed chamber is seen underneath the preceding coil, and the dome-shaped initial portion projects above. The aperture is a slit at the ventral suture of the final chamber. The test is opaque with very fine protopores. Transverse sections show the chamber-walls bending up ventrally, to form the narrow umbilicus and open umbilical foramen as in *Gyroidinoides*.



TEXT-FIG. *83—Rotaliatina mexicana* Cushman. (*a*) dorsal side; (*b*) ventral side with open umbilicus; (*c*) apertural view; (*d*) vertical section showing the open umbilical foramina. From unit 5, all ×65.

This species, the genotype of *Rotaliatina*, is more primitive than *R. buliminoides* (Reuss) of the European Oligocene. The latter is more lofty and the aperture and septal foramina are shorter and rounder.

Dimensions of the Ecuador specimens: diameter, 0.60–0.80 mm., height 0.40–0.50 mm.

Family GAVELINELLIDAE Hofker, new family

This new family includes the genera *Gavelinella*, *Gavelinopsis*, *Gavelinonion*, and *Stensiöina*. In their more primitive forms these genera always show pores only at the ventral side, but their more highly developed species may also have pores on the dorsal walls of the later chambers. The septal walls are invariably double in all these genera. On the ventral side there are umbilical foramina covered by more or less pronounced lips, indicating a close relationship to *Gyroidinoides* and *Valvulineria*.

In one group of species the umbilical cavity is filled up by a knob of calcite, and these forms comprise the genus *Gavelinopsis* Hofker. It is not limited to the Cretaceous, as Tertiary and Recent species are known.

Genus GAVELINELLA Brotzen, 1942

This genus is characterized by the following features: test trochoid; walls always granulate in polarized light; septal walls always double; at dorsal side all chambers visible, at ventral side only those of the last formed whorl; umbilicus open, with small to large lips covering open umbilical apertures; sutural aperture a slit or arched opening along the ventral suture; in older chambers the umbilical and the septal foramina are separated, but in the final chamber they are connected. Pores in more

primitive species only on the ventral side, but in more advanced species (uppermost Cretaceous and Tertiary) also on the dorsal side.

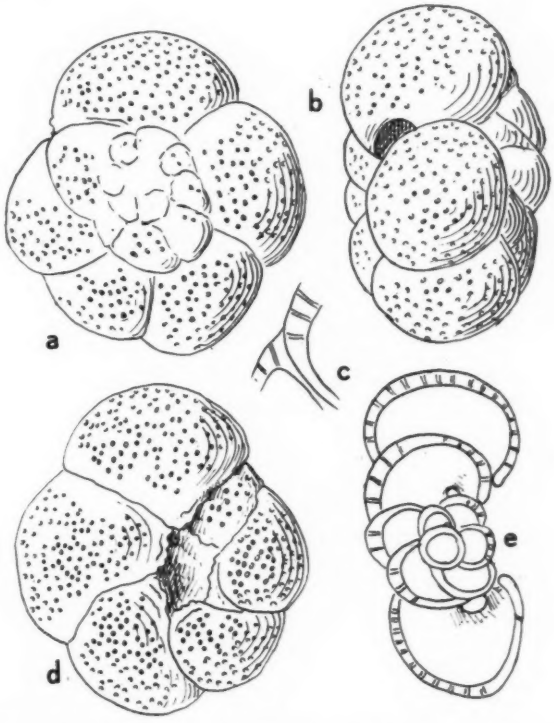
This genus is first known in the Lower Cretaceous and ranges through the Lower Tertiary. Many of the Upper Cretaceous species show fine pores in their early development, gradually becoming coarser.

GAVELINELLA POMPILIOIDES Galloway and Heminway)
Text-fig. 84

Anomalina pompilioides GALLOWAY & HEMINWAY, 1941, New York Acad. Sci., Si. Surv. Porto Rico and Virgin Is., vol. 3, pt. 4, p. 389, pl. 22, fig. 3.

This species occurs abundantly at locality 6 but was not listed by Cushman & Stainforth. Test roughly circular in outline, margin lobulated; about six chambers in last formed whorl, inflated with depressed sutures; usually a distinct ventral umbilicus, with narrow umbilical lips on the chambers, covering very narrow umbilical foramina; irregular early coils visible on the dorsal side, but early chambers indistinct; last formed whorl (and sometimes earlier whorls) almost planispiral; wall yellowish but transparent, smooth, with coarse pores on both sides and at the margin; margin broadly rounded; aperture at the ventral side of the last chamber, near to the margin, arched, without a distinct lip. Diameter 0.50—0.70 mm. thickness about 0.30 mm.

This species was described from the Oligocene and is common in the Caribbean Tertiary. It is closely allied to, possibly even identical with, *G. lellingensis* Brotzen from the Paleocene of Sweden. Evidently this genus ranges above the Upper Cretaceous into the Lower Tertiary, and it may be that some Tertiary and Recent forms



TEXT-FIG. *84—Gavelinella pompilioides* (Galloway & Heminway). (*a*) dorsal side with irregular initial part; (*b*) apertural view; (*c*) section at a suture, showing the double septal wall; (*d*) ventral side; (*e*) vertical section. From unit 6, *a,b,d,e,* ×65: *c,* ×240.

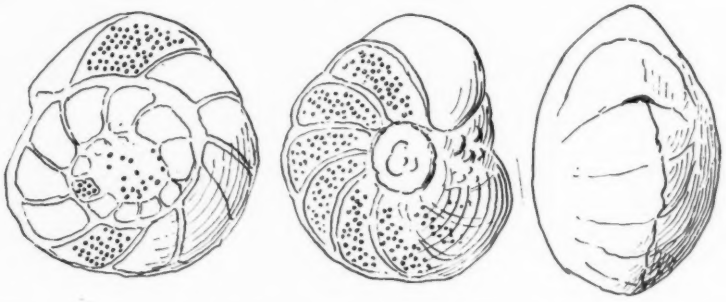
known as *Anomalina* are derived from the Lower Tertiary forms of *Gavelinella*.

Genus GAVELINOPSIS Hofker, 1951
GAVELINOPSIS PERLUCIDA (Nuttall)
Text-fig. 85–87

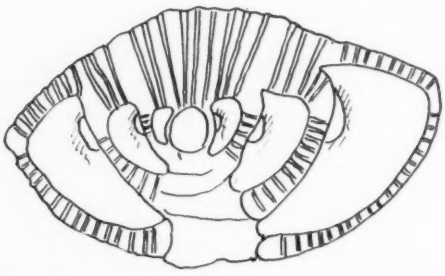
Cibicides perlucida NUTTALL, 1932, Jour. Paleont., vol. 6, p. 33, pl. 8, fig. 10–12; STAINFORTH, 1948, ibid., vol. 22, p. 129, pl. 25, fig. 8–10; CUSHMAN & STAINFORTH, 1951, ibid., vol. 25, p. 163.

This species, a large one, is abundant in Unit 12 but scarcer in others. The very thick walls are very hyaline with large pores. On the dorsal side all chambers are visible, sutures running obliquely backward and slightly curved. The central part of the dorsal face is covered by a thick boss of calcite, which is pierced by coarse pores. On the ventral side only the last formed whorl is visible, sutures curved backward, the chambers not reaching the center of the test, which is occupied by a sharply defined calcite knob. The margin is broadly rounded in larger tests, sharper in smaller specimens. The ventral side is poreless in young tests, but pierced by numerous large pores in older tests. Sections show the chamber-walls ending at the ventral knob, so that if there were no knob there would be umbilical foramina. The septal foramina are arched and ventrally placed. The margin is poreless, the septal walls double.

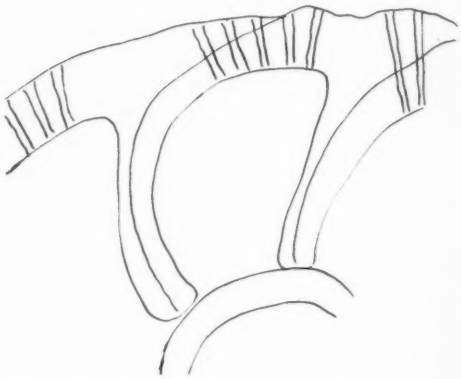
This species is undoubtedly a *Gavelinopsis* and not a *Cibicides*. It is very similar to *G. voltziana* (d'Orbigny), a species abundant in the Upper Cretaceous of Europe, differing mainly in the appearace of pores on the dorsal face. The writer has analyzed many American Upper Cretaceous species formerly referred to *Anomalina*, *Planulina* and *Cibicides*, and up to now every one of them has proved to be a *Gavelinopisis*. Presumably, therefore, *G. perlucida* is a Tertiary descendant of one of these Cretaceous forms allied to *G. voltziana*.



TEXT-FIG. *85—Gavelinopsis perlucida* (Nuttall). Three views of a test from unit 12, ×30.



TEXT-FIG. *86—Gavelinopsis perlucida* (Nuttall). Transverse section, ×65.



TEXT-FIG. *87—Gavelinopsis perlucida* (Nuttall). Part of a horizontal section, showing the double septal walls, ×180.

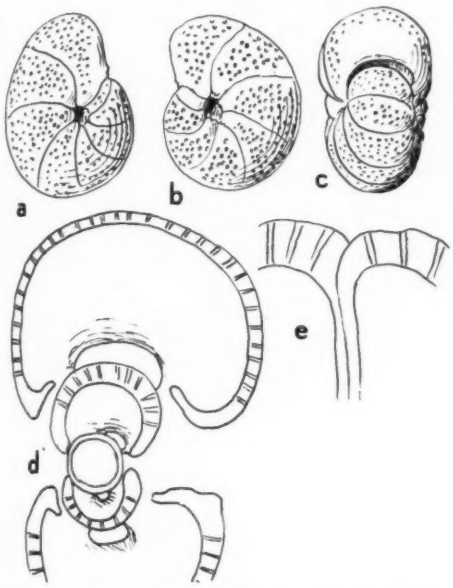
Genus GAVELINONION Hofker, 1951

Planispirally coiled Gavelinellidae with distinct pores in the walls, double septal walls, umbilici on both sides, with umbilical foramina often covered by short lips, and marginal sutural apertures. Many species have been placed by previous authors in *Anomalinoides* and *Nonion*.

GAVELINONION CHIRANUS (Cushman and Stone)
Text-fig. 88

Anomalina chirana CUSHMAN & STONE, 1947, Cushman Lab. Foram. Res., Spec. Pub. 20, p. 25, pl. 4, fig. 1; CUSHMAN & STAINFORTH, 1951, Jour. Paleont., vol. 25, p. 161, pl. 28, fig. 7,8.

This species is common at locality 6. The Ecuador specimens are identical with topotypes from the Peruvian Chira shale. The original description clearly places this species in the vicinity of "*Nionion*" *soldani* (d'Orbigny), "*Nonion*" *pompilioides* (Fichtel & Moll), and orther representative species of *Gavelinonion*. Transverse sections show the diagnostic features of double septal walls and umbilical foramina on both sides. The trochoid initial whorl and slightly ventral situation of the later arched apertures are also typical, seen in species of *Gavelinonion* ranging from Maestrichtian to Recent.



TEXT-FIG. 88—*Gavelinonion chiranus* (Cushman & Stone). (*a,b,c,*) three views of a test from locality 6, ×65; (*d*) vertical section, showing the septal foramina and the open umbilical foramina on both sides, ×180; (*e*) part of tangential section, showing the double septal walls ×240.

Family MARGINOLAMELLIDAE
Genus CANCRIS Montfort, 1808

The genotype, *Cancris auriculus* var. B Fichtel & Moll, shows a compressed test with very hyaline walls; distinct but fine pores over most of the test, but not on the umbilical lips, the apertural face, nor the acute margin; a wide umbilical foramen on the ventral side, covered by umbilical lips; a wide, rounded septal foramen, suturally placed; umbilical and septal foramina separated.

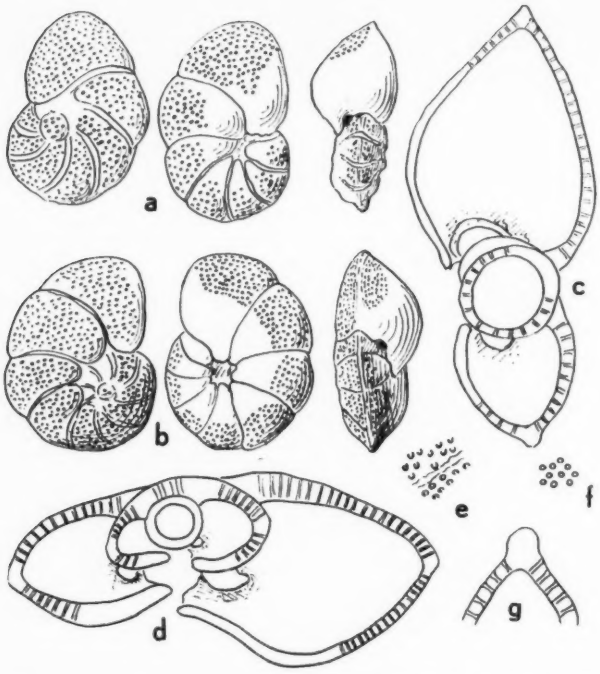
CANCRIS COCOAENSIS Cushman
Text-fig. 89

Cancris cocoaensis CUSHMAN, 1946, Cushman Lab. Foram. Res., Spec. Pub. 16, p. 35, pl. 7, fig. 5.

Cibicides cf. *mississippiensis* CUSHMAN & STAINFORTH, 1951, Jour. Paleont., vol. 25, p. 162, pl. 28, fig. 15.

Specimens from locality 12 have been compared with topotypes from the Eocene Cocoa sands of Alabama and seem identical. In dorsal aspect most of the chambers are visible, though the last formed whorl tends to overlap. The sutures are distinctly curved backward, clear, slightly limbate, and very distinct. The dorsal chamber-walls are pierced all over by fine but very distinct pores. The margin is sharp but not keeled, without pores, so that from the side it appears as a poreless ridge connected to the poreless apertural face of the last chamber. In ventral aspect only the last whorl is visible, the chamber-walls porous near the margin but poreless in a wide area around the open, depressed umbilicus. The aperture is an arched slit ventrally placed on the ventral suture.

Transverse sections show the poreless parts of the ventral chamber-walls to be the umbilical lips covering a wide, open umbilical aperture. The septal foramina are wide and ventrally placed, but separate from the



TEXT-FIG. *89*—*Cancris cocoaensis* Cushman. (*a*) three views of a test from locality 7, ×65; (*b*) three views of a test from locality 12, ×65; (*c,d*) vertical sections, showing umbilical and septal foramina and the poreless margin, ×180; (*e*) pores at margin, ×180; (*f*) pores on chamber-wall, ×180; (*g*) marginal part of transverse section, ×240.

umbilical aperture. The poreless margin shows up distinctly in these sections.

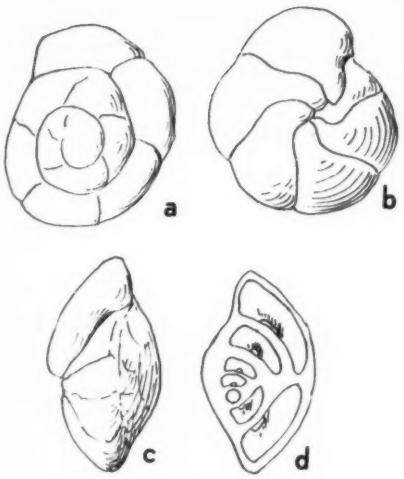
All these features confirm Cushman's allocation of the species to *Cancris*. *Anomalina* (*"Cibicides"*) *mississippiensis* Cushman, as first described from the Eocene of Alabama, differs in its totally overlapping, involute chambers on the dorsal side, and in its porous, non-umbilicate ventral side.

Family EPONIDIDAE
Genus EPONIDES Montfort, 1808
EPONIDES UMBONATUS (Reuss)
Text-fig. 90

Eponides umbonatus (Reuss) auct., incl. CUSHMAN & STAINFORTH, 1951, Jour. Paleont., vol. 25, p. 159, pl. 27, fig. 28,29.

This species occurs in most of the type-samples of the Eocene of Ecuador. At the dorsal side the earlier coils are visible but the initial chambers can hardly be discerned, being covered by a thick layer of calcite. The later chambers are narrow and long, with the short sutures nearly radial or slightly bent backward. The last formed whorl is flatter than the earlier ones, which are raised in a blunt cone. The margin is acute or slightly rounded. On the ventral side only the chambers of the last formed whorl are visible, with oblique sutures bending abruptly into the center at about two-thirds of their length, measured from the periphery. In the apertural face there is an indentation near the margin, falsely suggesting an analogy with *Alabamina*. The aperture is a narrow slit at the ventral suture. The septal foramina are also slits at the ventral sutures. No trace of a toothplate can be found, neither in the Ecuador specimens nor in comparative specimens from the Lower Tertiary of Holland. The walls are relatively thick, opaque, with very fine protopores.

All these characters point to close relationship with *Eponides repandus* the genotype. Recently Uchio (1953, p. 157) has placed *E. umbonatus* in his genus *Pseudoeponides*. However, the genotype *Pseudo-*



TEXT-FIG. *90—Eponides umbonatus* (Reuss). External views and section of a specimen from locality 12, ×65.

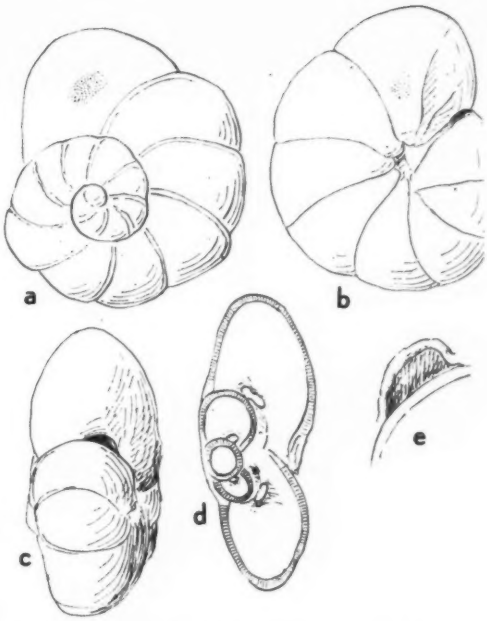
eponides japonicus Uchio shows a very highly developed toothplate and toothplate-foramina at the dorsal side of each chamber, but there is no toothplate in *E. umbonatus*. Furthermore the form figured by Uchio as *E. umbonatus* appears to have pores on the dorsal side, but there are no such pores on the original form of this species.

EPONIDES? ANCONENSIS Hofker, n. sp.
Text-fig. 91

Eponides cocoanensis CUSHMAN & STAINFORTH, 1951 (not Cushman, 1946), Jour. Paleont., vol. 25, p. 159, pl. 27, fig. 31.

This species is abundant in Unit 4. All chambers are visible on the dorsal side, only those of the last formed whorl on the ventral side. The dorsal sutures are distinct and slightly raised, curved backwards, the ventral ones radial and slightly curved, reaching the center. The aperture is a narrow slit at the ventral margin, with a slightly protruding border, and all the septal foramina are also ventral. No umbilical foramina could be found. The walls are thin with some secondary thickening on the ventral side. The whole test is finely porous with a rounded margin.

The taxonomic place of this species is somewhat doubtful. It resembles several true species of *Eponides* from the Upper Cretaceous, but lacks the sharpened margin



TEXT-FIG. *91—Eponides* (?) *anconensis*, n. sp. (*a,b,c*) external views of holotype from locality 4; (*d*) vertical section. All ×65. (*e*) aperture, ×180.

typical of most species. There is a superficial resemblance to *Valvulineria chirana* from the Chira shale, but the new species has no umbilical foramina. It was compared with topotypes of *Eponides cocoaensis* but is distinct.

Type locality.—Sea cliffs at Ancon, southwest Ecuador. Type level: the Clay Pebble beds, probably late Middle Eocene. Type specimens have been placed in the Cushman Collection, U. S. National Museum, P4812 (4 "paratypes").

Family GLOBIGERINIDAE

Stainforth (1948) and Cushman & Stainforth (1951) have listed six species of Globigerinidae in the Eocene of Ecuador, identifying them (partly tentatively) with known species of the Caribbean Eocene. In the present study these plaktonic forms have been carefully compared with Eocene suites from the Cocoa sands of Alabama and from other formations, as well as with topotypes of the species named by Cushman & Stainforth, but they are almost entirely different. In some cases a superficial resemblance of

species was noted which, however, was not apparent under closer scrutiny. *Globigerina danvillensis* Howe & Wallace is the only Ecuadorean species also known in the Carribbean Eocene: all the others are new.

This totally new suite of *Globigerinas* possibly is due to an Antarctic influence on the planktonic fauna of the area. At present we know very little about Eocene planktonic faunas of the Antarctic region, but the existence in Tertiary time of cold polar currents along the western coastline of South America has already been postulated (Stainforth, 1948, p. 137–139; Nygren, 1950, p. 2006). Another explanation would be that planktonic species are less widely distributed than has been thought and that long-range identifications have been based on over-generalised comparisons.

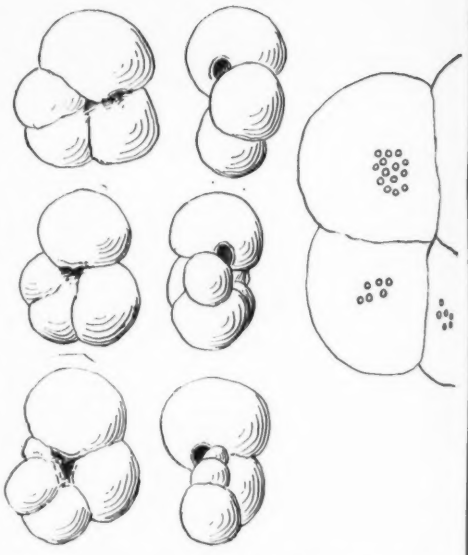
In the descriptions below, the normal features (*e.g.*, chamber arrangement and apertural details) are supplemented by reference to the "pore-index" (Hofker, 1950b). This index is established as follows: a camera-lucida drawing of a portion of the test is made at high magnification, usually 500×, all the pores being accurately outlined; a card with an opening of one square centimeter is then laid on the drawing, and the number of pores seen through the opening is counted in several random positions; the average of these counts is the first figure of the pore-index; the second figure of the index is the average diameter in millimeters of the drawings of the pores. The pore-index is expressed in the form 7—1.5, ×500, indicating an average of seven pores per square centimeter, with average diameter of 1.5 mm., at a magnification of 500×.

It has been found that the pore-index is a very consistent character of any given species. In some cases it changes from the earlier to the later chambers, but this change is itself a constant character of the species.

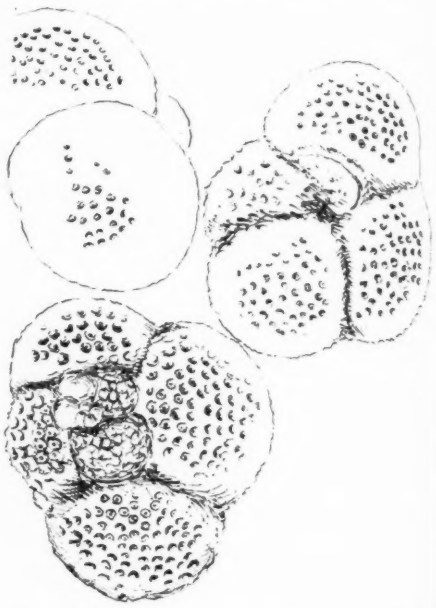
GLOBIGERINA DANVILLENSIS Howe & Wallace
Text-fig. 92

Globigerina danvillensis HOWE & WALLACE, 1932, Louisiana Dept. Conser., Geol. Bull. no. 2, p. 74, pl. 10, fig. 9; *Stainforth*, 1948, Jour. Paleont., vol. 22, p. 117, pl. 25, fig. 24,25.

This species is abundant in Unit 6. Test small, diameter 0.33–0.36 mm., thickness 0.18–0.20 mm. About four chambers in the last formed whorl, increasing regularly in length with a ratio of about 1.3:1 between successive chambers. Chambers of the last whorl arranged in a nearly flat spiral.



TEXT-FIG. *92*—*Globigerina danvillensis* Howe & & Wallace. Ventral and apertural view of three specimens, ×65; ventral view with pores partly indicated, ×180.



TEXT-FIG. *93*—*Globigerina paravenezuelana*, n. sp. Three views of the holotype from locality 5.

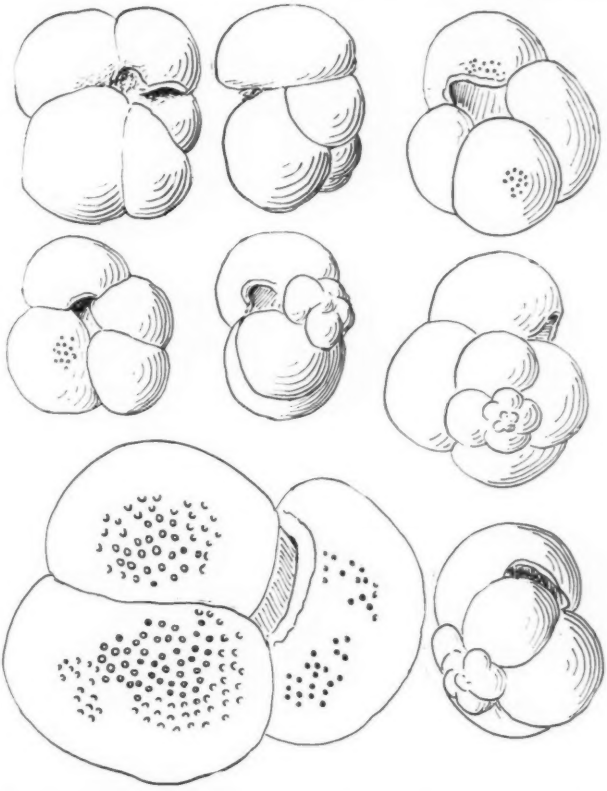
All chambers visible on the dorsal side. On the ventral side only chambers of the last whorl visible, showing a deep umbilical space at the center where the chambers are much inflated. The rounded inflated chambers form a strongly lobulate margin. The aperture is near to the margin and cannot be seen from the ventral side since it is covered by a narrow lip; it is always visible in apertural view as a small semicircular opening with a distinct brim. The pore-index is 4.5—2×500. The surface of the wall is smooth without any reticulation. The occurrence of fine spines on the surface is not a significant character; they are the bases of the radial pseudopodia and may or may not be preserved.

GLOBIGERINA PARAVENEZUELANA Hofker, n. sp.
Text-fig. 93,94

Globigerina triloculinoides (?) STAINFORTH, 1948, Jour. Paleont., vol. 22, p. 117, pl. 25, fig. 32,33.

Test of medium size, greater diameter 0.30–0.48 mm., lesser diameter 0.27–0.40 mm., thickness 0.24–0.35 mm. Usually four chambers in the last formed whorl, the rate of increase of chamber-size augmenting with growth, the average length-ratio of successive chambers being 1.1:1, whereas between the last two and the previous two of the final coil it is 1.3:1. The last two chambers are very much inflated toward the ventral side. There is a small umbilical area on the ventral side, overhung by the large aperture. The aperture is very wide and always bordered by a distinct rim; it is always in the umbilical area and not near the margin. The pore-index is 4 (5)—2, ×500. The surface of the test shows conspicuous pits in which the pores are situated, but there is no real reticular ornamentation, especially in the last formed chambers.

Type locality.—Locality 5, between the two main tributaries of Rio Jusá, 14 to 15 km. E.S.E. of Colonche, southwest Ecuador.



TEXT-FIG. *94*—*Globigerina paravenezuelana*, n. sp. Views of several tests from localities 5a and 6, ×65, an enlarged ventral view showing pores, ×180.

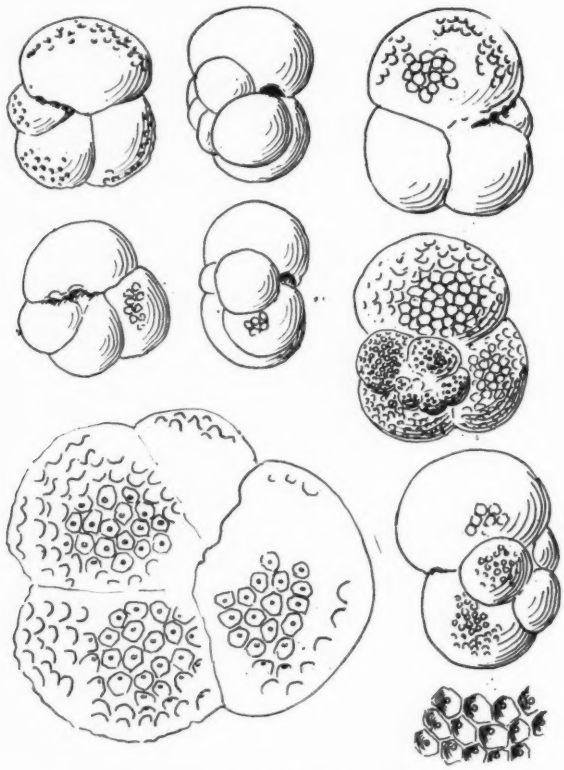
Type level: Jusá formation, Upper Eocene. Also found at localities 5a, 6, 7, 9, 12 usually abundant. Type specimens deposited in the Cushman Collection, U. S. National Museum, P4813 (holotype) and 4814 (15 paratypes).

GLOBIGERINA PROTORETICULATA Hofker, n. sp.
Text-fig. 95

Globorotalia centralis STAINFORTH, 1948, Jour. Paleont., vol. 22, p. 118.

Test of medium size, greater diameter 0.33–0.45 mm., lesser diameter 0.20–0.36 mm., thickness 0.24–0.33 mm. Usually four chambers in the last formed whorl, of which the oldest is often scarcely visible from the ventral side. The three last formed chambers increase in length very regularly, with a ratio of 1.28:1. Chambers very much inflated toward the ventral side, nearly circular in side view. On the dorsal side all chambers are visible, on the ventral side only the last three or four, meeting at the center so that no real umbilicus is formed only a more or less deep cavity. The aperture is a short, narrow sutural slit running into this cavity, with an inconspicuous rim. Pore-index in the last formed chambers 2(3) – 1(2), ×500, but the density of pores is higher on the earlier chambers, decreasing gradually with growth. The earlier, more porous chambers are ornamented by a clear honeycomb reticulation, but as usual for the genus this pattern gradually becomes indistinct on the younger chambers.

Type locality.—Common in Units 5 and 12 between the two main tributaries of Rio Jusá, 14 to 15 km. E.S.E. of Colonche, southwest Ecuador. Type level: Jusá formation, Upper Eocene. Type specimens have



TEXT-FIG. *95*—*Globigerina protoreticulata*, n. sp. Cotypes: on right, three views of a large specimen; upper left and middle left, two views each of smaller specimens, all ×65; below, enlarged view showing pores and reticulation, ×180; bottom right, pores and reticulation, ×240.

been deposited in the Cushman Collection, U. S. National Museum, P4815 (4 syntypes).

GLOBIGERINA STAINFORTHI, Hofker, n. sp.
Text-fig. 96,97

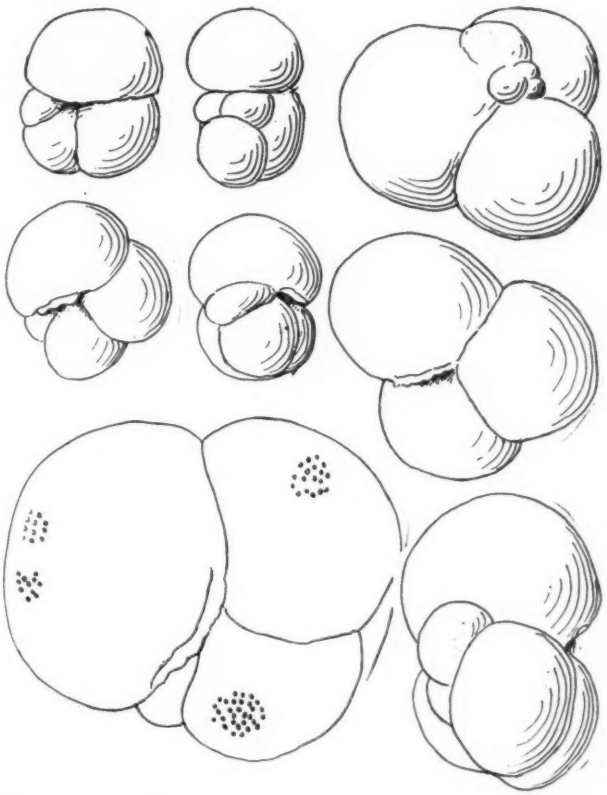
Test medium size to large, greater diameter 0.36–0.75 mm., lesser diameter 0.30–0.50 mm., thickness 0.26–0.48 mm. Usually only three chambers visible on the ventral side, though sometimes part of a fourth can be seen. Chambers large, especially the last which forms nearly half the test. The rate of increase of chamber-size is remarkably high, the length-ratio on the ventral side being 1.35:1. Chambers greatly inflated on both sides. On the dorsal side all the chambers may be visible, but in many tests the final coil envelops the earlier chambers. On the ventral side three chambers meet at the center and there is no umbilical cavity. The aperture is a very narrow slit, often nearly invisible, with an inconspicuous rim, running suturally from the center. Pore-index 11−1, ×500. Surface nearly smooth, with no reticular ornamentation.

Type locality.—Sea cliffs immediately west of Punta Mambra, southwest Ecuador. Type level, Seca shale, Upper Eocene; abundant. Type specimens have been deposited in the Cushman Collection, U. S. National Museum, P4816 (6 syntypes).

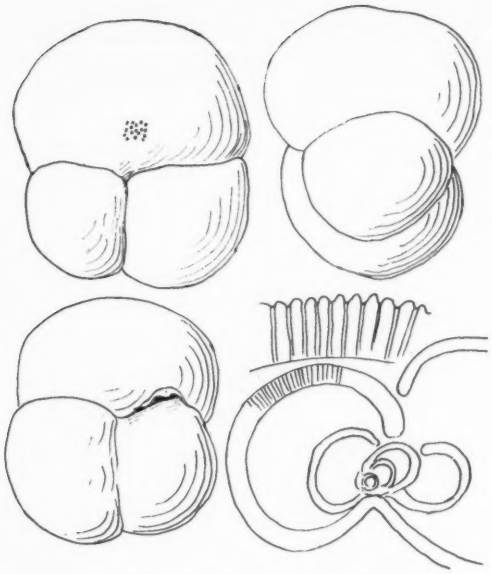
GLOBIGERINA PSEUDOCRETACEA Hofker, n. sp.
Text-fig. 98

Globigerina wilsoni (?) STAINFORTH, 1948, Jour. Paleont., vol. 22, p. 117, pl. 26, fig. 1–3.

Test of medium size, diameter about 0.45



TEXT-FIG. *96—Globigerina stainforthi*, n. sp. Cotypes: right vertical row, three views of same specimen, ×65; upper left pair and middle left pair, two more specimens, ×30; lower left, enlarged view with pores partly indicated, ×180.



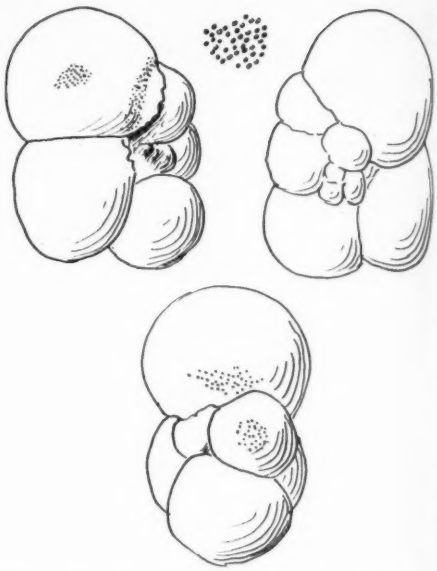
TEXT-FIG. *97—Globigerina stainforthi*, n. sp. External views and section of a totally involute specimen from the type-locality (5a), ×65; inset, section of the wall, showing pores and pore-pits, ×240.

by 0.36 mm., thickness 0.27 mm. All chambers visible dorsally, the five of the last whorl visible ventrally. On the ventral side there is a true umbilicus flanked by crenulated lips over the apertures. Chambers increase gradually in length, with a ratio of 1.25:1 between successive chambers. Aperture reaches toward the margin from the umbilical cavity, with a prominent crenulated lip. Wall very smooth, with very fine pores: pore-index 17—1, ×500.

Type locality.—Sea cliffs at Ancon, southwest Ecuador. Type level: Clay Pebble beds, late Middle Eocene. Type specimens have been deposited in the Cushman Collection, U. S. National Museum, P4817 (2 syntypes).

GLOBIGERINA PARATRILOCULINOIDES Hofker, n. sp. Text-fig. 99

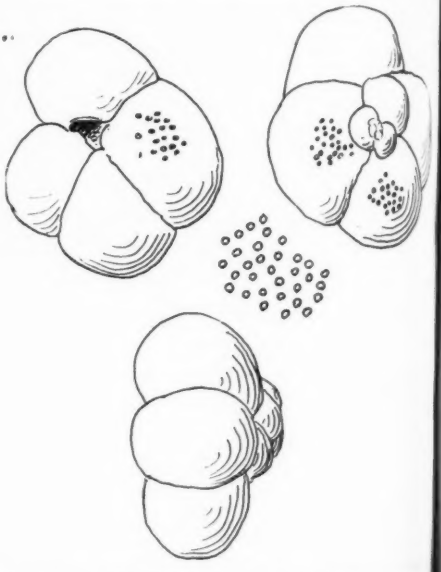
Test of medium size, diameter 0.42 by 0.36 mm., thickness 0.24 mm. All chambers visible on dorsal side, only those of the last whorl on the ventral side, reaching almost to the center but leaving a small umbilical cavity free. Chambers fairly inflated towards both sides, increasing slowly in length with a



TEXT-FIG. *98—Globigerina psuedocretacea*, n. sp. Three views of the holotype from locality 4, ×80; inset, pores, ×235.

ratio of 1.1 or 1.2:1 between successive chambers. Surface smooth, pore-index 5—1.5, ×500. Aperture a narrow opening at the umbilical cavity.

This species somewhat resembles *G.*



TEXT-FIG. *99—Globigerina paratriloculinoides*, n. sp. Three views of holotype from locality 2, ×80; inset, pores, ×235.

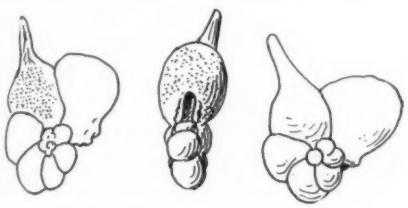
triloculinoides Plummer but differs from topotypes of that species in the total lack of any honeycomb ornamentation.

Type locality.—A quarry in white tuffaceous shale on the hillside north of the Manta-Portoviejo road between the 22 km. and 23 km. posts, 14 km. due west of Portoviejo, western Ecuador (locality 2). Type level: Paleocene, unnamed formation unconformable below the San Mateo formation. Type specimens have been deposited in the Cushman Collection, U. S. National Museum, P4818 (15 syntypes).

Genus HANTKENINA Cushman, 1924
HANTKENINA PRIMITIVA
Cushman & Jarvis
Text-fig. 100

Hantkenina alabamensis var. *primitiva* CUSHMAN & JARVIS, 1929, Cushman Lab. Foram. Res., Contr., vol. 5, p. 16, pl. 3, fig. 2,3 (see BRONNIMANN, 1950, as below).
Hantkenina (*Hantkeninella*) *primitiva*, BRONNIMANN, 1950, Jour. Paleont., vol. 24, p. 416, pl. 56, fig. 4,26,27.
Hantkenina alabamensis CUSHMAN & STONE, 1947, Cushmann Lab. Foram. Res., Spec. Pub. 20, p. 25, pl. 3, fig. 14,15; STAINFORTH, 1948, Jour. Paleont., vol. 22, p. 127, pl. 25, fig. 3; CUSHMAN & STAINFORTH, 1951, ibid., vol. 25, p. 161, pl. 28, fig. 9.

This species was found at localities 5a and 6. The specimens are all very small, diameter about 0.24 mm. They never show more than one spine, or at most two. The five to



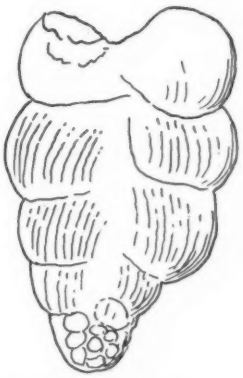
TEXT-FIG. *100*—*Hantkenina primitiva* Cushman & Jarvis. From locality 5a, ×80.

seven small chambers following the proloculus are spineless. They have been compared with topotypes of *H. alabamensis* Cushman from the Eocene Cocoa sands of Alabama but are not identical. They do not differ from the smaller type figured by Cushman & Jarvis in their description of the variety *primitiva*, nor from the figures given by Bronnimann when he raised this variety to specific rank. The walls are not granulated and the pores are fine but distinct. A poreless area surrounds the aperture and connects with the spine, also poreless.

Genus GÜMBELINA Egger, 1899
GÜMBELINA (HETEROHELIX)
NAVARROENSIS Loeblich
Text-fig. 101

Heterohelix navarroensis LOEBLICH, 1951, Cushman Found. Foram. Res., Contr., vol. 2, p. 107, pl. 12, fig. 1–3, tf. 1; 1953, Micropaleontologist, vol. 7, no. 2, p. 41.

Test very small, length 0.20 mm., greatest width 0.12 mm. Subtriangular in side view, biserial chambers broad, separated by almost horizontal sutures. Periphery lobu-



TEXT-FIG. *101*—*Gümbelina* (*Heterohelix*) *navarroensis* Loeblich. Specimen from locality 12, ×235.

lated, since the chambers are strongly inflated. Margin rounded, but not broadly so. The five chambers of the initial coiled part not inflated. Wall calcareous, hyaline, surface distinctly striate, the striae very slightly oblique, with very fine pores. Aperture an arched opening at the axis.

This species is very similar to *Heterohelix navarroensis* as described by Loeblich. It was plentiful in the Upper Eocene at locality 12, and the specimens show the same type of air-filled preservation as the other species in this fauna. Hence it seems most unlikely that it has been re-deposited from a *Navarro* (Maestrichtian) fauna, especially as there is no other evidence of reworking. It differs from *Gümbelina cubensis* which lacks the striae, and from "*Gümbelina*" (*Stainforthia*) *venezuelana* which has a toothplate. It may be a late offspring of *Heterohelix navarroensis* Loeblich.

REFERENCES

CUSHMAN, J. A., 1948, Foraminifera: their classification and economic use: Harvard Univ. Press (4th Ed.).

—— & PARKER, F. L., 1947, *Bulimina* and related foraminiferal genera: U. S. Geol. Surv., Prof. Pap. 210–D, p. 55–176.

—— & STAINFORTH, R. M., 1951, Tertiary Foraminifera of coastal Ecuador: Part I, Eocene: Jour. Paleont., vol. 25, p. 129–164.

FINLAY, J. A., 1947, New Zealand Foraminifera: key species in stratigraphy: New Zealand Jour. Sci. Tech., vol. 28, no. 5 (sec. B), p. 272–275, etc.

HENSON, F. R. S., 1948. Larger imperforate Foraminifera of south-western Asia: Brit. Mus. (Nat. Hist), London.

HOFKER, J., 1927, Die Foraminiferen aus dem Senon Limburgens; VI–VII: Natuurh. Maandblad, Limburg, Jaarg. 16, p. 125–128, 173–176.

——, 1950a, Siboga-Reports; The Foraminifera of the Siboga Expedition, pt. III: Uitkomst. zool. bot. oceanogr.-geol. Gebied, Monogr. IVa.

——, 1950b, Is more concerted effort possible in establishing the regional significance of planktonic Foraminifera as indices of geologic age?: The Micropaleontologist, vol. 4, no. 2, p. 16–17.

——, 1951, The toothplate Foraminifera: Archives Néerl. Zool., vol. 8, pt. 4, p. 353–373.

——, 1952. Zur Fassung der Foraminiferengattung *Bolivinoides* Cushman: Geol. Jahrb., vol. 66, p. 377–382.

NYGREN, W. E., 1950, Bolivar geosyncline of northwestern South America: Amer. Assoc. Petr., Geol., Bull., vol. 34, p. 1998–2006.

REUSS, A. E., 1862, Paläontologische Beiträge: K. Akad. Wiss. Wien, Math.-Naturw. Cl., Sitzber., Bd. 44 (1861), Abt. 1, p. 308–309.

STAINFORTH, R. M., 1948, Applied micropaleontology in coastal Ecuador: Jour. Paleont., vol. 22, p. 113–151.

——, 1952, Nomenclature of uniserial calcareous Foraminifera: Cushman Found. Foram. Research, Contr., vol. 3, pt. 1, p. 6–14; pt. 3-4, p. 146.

UCHIO, T., 1953, On *Eponides* and *Pseudoeponides:* Jap. Jour. Geol. Geogr., vol. 23, p. 156–159.

VISSER, A. M., 1951, Monograph on the Foraminifera of the type-locality of the Maestrichtian (South-Limburg, Netherlands): Leidse Geol. Meded., vol. 16, p. 197–359.

JOURNAL OF PALEONTOLOGY, VOL. 30, NO. 4, P. 959–980, JULY 1956

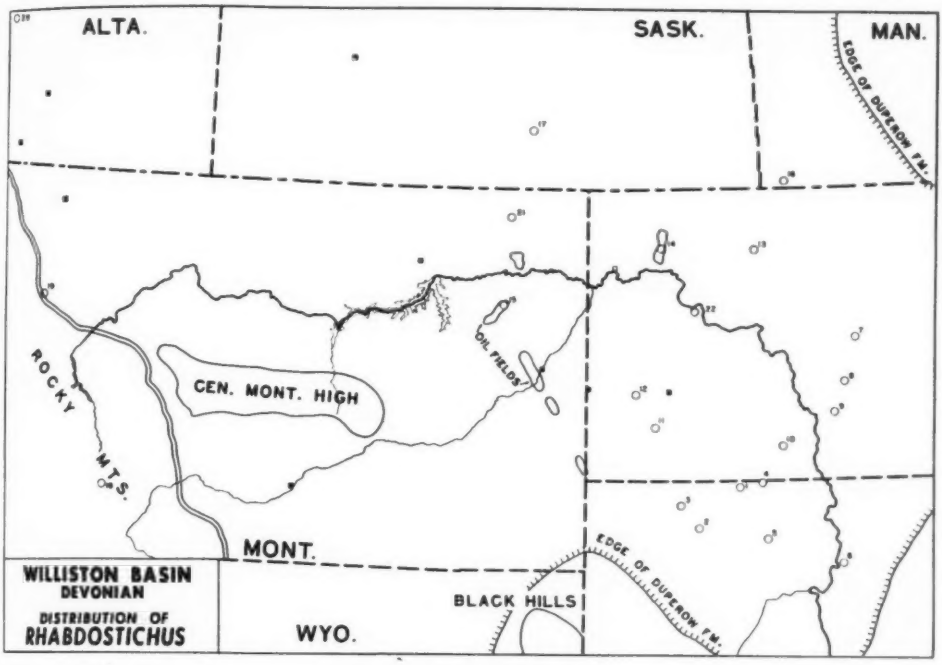
PALEONTOLOGICAL NOTES

STRATIGRAPHIC POSITION OF THE UPPER DEVONIAN BRANCHIOPOD *RHABDOSTICHUS* IN THE WILLISTON BASIN*

JAMES LEE WILSON
Shell Development Company, Houston, Texas

In November 1952, the writer and J. R. McGehee of the Denver Area, Shell Oil Company, discovered in the core of Shell No. 1 Veal, Perkins County, South Dakota, a thin zone of tiny ostracod-like fossils forming a coquina in dense limestone. Soon after, these fossils were also found in Late Devonian cores from Shell No. 1 NPRR (Richey) and the Amerada No. 1 Iverson, over 200 miles north and northwest of the Veal well. The table presented shows 22 localities from which this fossil is now known. They include 19 widely scattered wells in the Williston basin and three outcrop occurrences in the Montana and Alberta Rocky Mountain Front Range (Text-fig. 1).

All the listed occurrences have been verified by the writer except that of Norcanols No. 1 Ogema. In this well, as in Souris Valley No. 1 Moore, the Central Canadian Sample Service and stratigraphers for the Canadian Geological Survey note the fossil as "abundant tiny pelecypods" (Wickenden & Price, 1952, p. 33). Several of the later discoveries of this fossil were made by Shell Oil personnel examining samples in Division offices of the Shell Oil Company Denver Area. The writer gratefully acknowledges this assistance by E. S. Earl, D. J. DeSautel, and H. Mayberry. The writer is also grateful to Dr. P. W. Taylor, Shell Oil of Canada, for recog-



TEXT-FIG. 1—Index map.

* Publication No. 82, Shell Development Company, Exploration and Production Research Division, Houston, Texas.

nizing the fossil in a Devonian section, measured by the latter, along Hummingbird Creek in the Canadian Rockies, north of Calgary.

SYSTEMATIC DESCRIPTIONS

RHABDOSTICHUS cf. R. PULEX (Clarke)

Text-fig. 3, fig. 1,3,6–9

Estheria pulex CLARKE, 1882, Amer. Jour. Sci., ser. 3, vol. 23, p. 476, pl. fig. 4.
Estheria pulex HALL & CLARKE, 1888, Paleont. New York, vol. 7, p. 206, pl. 35, fig. 10,11.
Rhabdostichus pulex RAYMOND, 1946, Bull. Mus. Comp. Zool., Harvard, vol. 96, no. 3, p. 276, pl. 5, fig. 4.

It will be noted that the fossil has been assigned to a species long known from the Hamilton group of New York State. The types from New York State have been examined and photographed and a comparison made between the western material and the New York specimens. Probably no essential differences are present when allowances are made for preservation and matrix, although the western specimens appear to be more elongated and, in general, to have one or two less concentric grooves than those from the Hamilton.

No detailed description of the fossil is given here because it is being studied in connection with the branchiopod section of the *Treatise on Invertebrate Paleontology* by Dr. Paul Tasch of the University of Wichita. The writer has furnished Tasch with material from outcrop and wells.

The organism was encased in a tiny bivalved carapace strongly resembling that of a small clam. Its length is generally 1 mm. or less. A pronounced beak and umbo are present and the shells are prosocline and prosogyre. The eccentricity of the beak is variable in material from the same sample population. The only ornamentation consists of 4 to 6 concentric grooves. Preservation apparently affects the strength of these, but they may generally be seen on all specimens in oblique lighting even if weakly represented. The grooves increase in strength to the ventral margin. Some thin sections of the specimens from Shell No. 1 Veal suggest that the grooves are caused by outer accretions of shell material. The shell material is lamellose and preserved with a dark resinous luster as in ostracod or trilobite tests in older Paleozoic rocks.

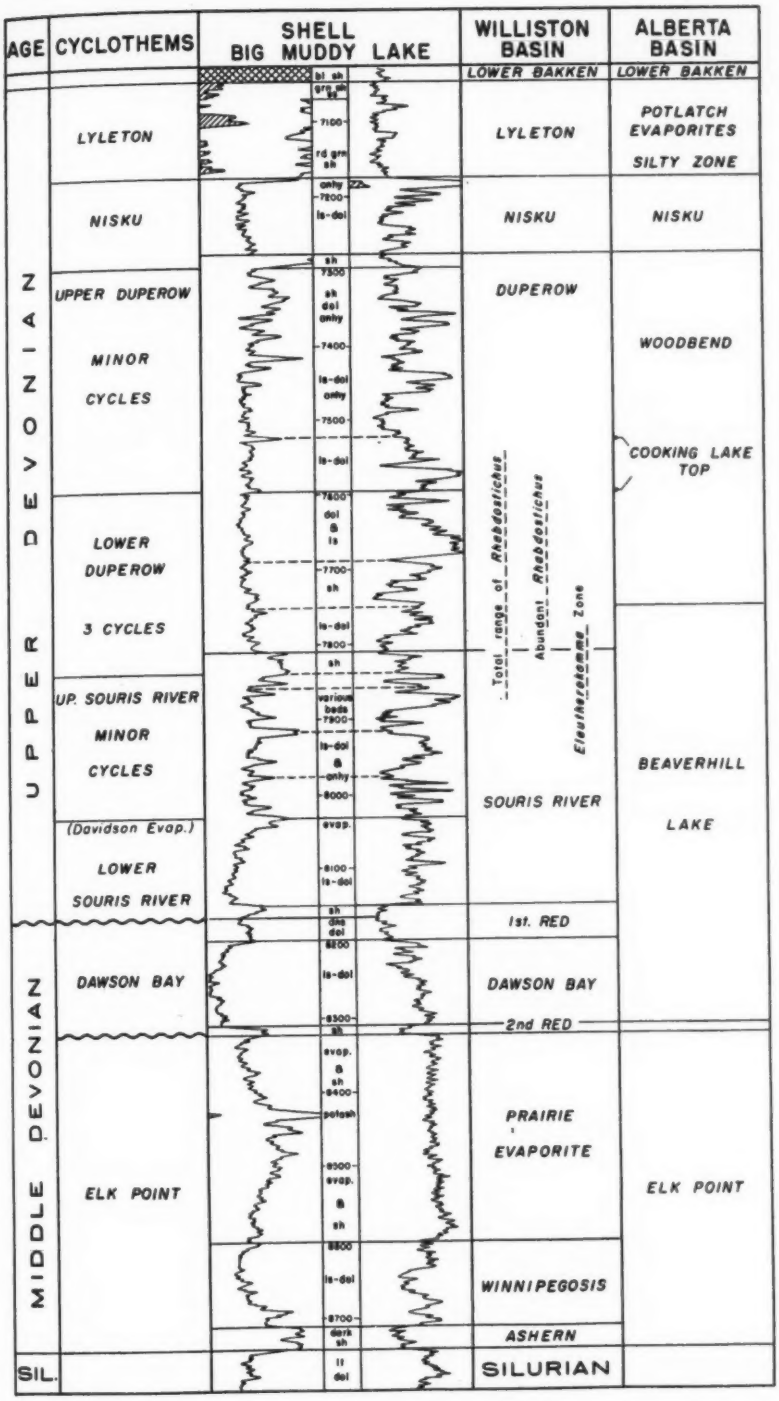
The proper taxonomic position of the organism is not yet known. The U. S. Geological Survey and Canadian Geological Survey paleontologists who examined specimens found by the Manitoba Bureau personnel in the Souris No. 1 Moore well considered the fossil to be an ostracod, *Aparchites canadensis*. This identification is considered in error since true *A. canadensis* differs from the specimens found by the writer in this interval in being much larger and in lacking the characteristic grooves of *Rhabdostichus*. True *A. canadensis* occurs both in Ontario and in the Williston basin much lower in the Devonian.

Specimens of *Rhabdostichus* resemble the ostracods *Eridoconcha* and *Cryptophyllus*. These are characteristic Ordovician forms, although rare specimens of the latter genus are reported from the Devonian in Europe and Canada (Levinson, personal communication; Bassler & Kellett, 1934, p. 310). *Eridoconcha* and *Cryptophyllus* are assigned to an ostracod group which retains moulted shells in the carapace (Levinson, 1951, p. 556). Seemingly, the *Rhabdostichus* specimens lack the hingement structures and sulci of these ostracods, and thin sections of *Rhabdostichus* fail to indicate that the grooved test is caused by outgrowing of younger moults from beneath the thickened outer edge of the older shell.

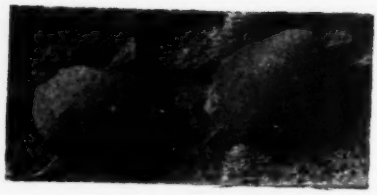
Rhabdostichus was described as a form *incertae sedis* by Raymond (1946) in a paper on fossil conchostracans. It lacks the characteristic small ornate ridges of "Estherians," although in shape and shell material it is similar to these forms. It probably is a member of some poorly known group of branchiopods confined to Middle Paleozoic rocks (Shrock & Twenhofel, 1953, p. 546–548).

STRATIGRAPHIC SIGNIFICANCE

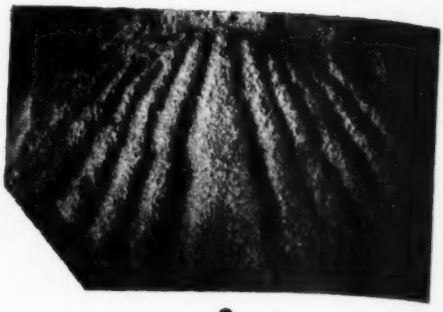
The species occurs in the Duperow formation in the Williston basin, and possibly as low as the Souris River formation. The Duperow, which is equivalent to the Jefferson formation of Montana and to the Woodbend of the Alberta basin, is divisible into cycles, each of which contains lower beds of bioclastic and pelletoid carbonate and upper strata of primary dolomite and bedded anhydrite (Andrichuk, 1951, p. 2377–78



TEXT-FIG. 2—Devonian correlations.

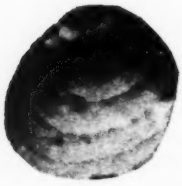


1



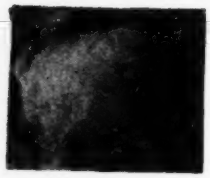
2

4

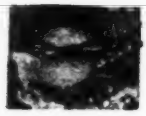


3

5



6



7

8

9

TEXT-FIG. 3—Devonian branchiopods.

1, *Rhabdostichus* cf. *R. pulex* (Clarke), left and right valves, ×26, core from Shell No. 1 Veal, depth 6753½ feet.

2, *Eleutherokomma* sp., dorsal valve, ×3, from core at Duperow-Souris River contact, Shell NP 22-3 (Cabin Creek), depth 8215 feet.

(Baillie, 1953, p. 31–33). The writer has arbitrarily chosen a gamma-ray intensity deflection at the top of one of the cycles to separate the Duperow into two parts.

As indicated on the accompanying table, the species is an excellent marker for the lower Duperow in the southern and eastern outer Williston basin (Dakota shelf); it occurs here fairly consistently from 10 to 100 feet beneath the mid-Duperow marker, and less than 100 feet above the base of the formation. The same general stratigraphic relations persist into the inner basin; although cores from Shell No. 1 NPRR (Richey area) contain the species more than 100 feet above the mid-Duperow marker. In Wanette No. 1 Lee (also in the inner basin), the form was found in samples below the top of the Souris River formation. Specimens from this well may have been picked from caved material, but the occurrences in the Shell No. 1 NPRR are not subject to question.

The range of the fossil is thus approximately middle and lower Duperow, possibly to upper Souris River formation, but it most commonly occurs in the lower Duperow; in the outer shelf areas on south, east, and west sides of the basin, it is known only from the lower Duperow. In the Rocky Mountain Front localities it occurs in beds equivalent to lower Duperow, as indicated by lithologic correlations made via Alberta basin subsurface control.

In all localities where it is possible to relate the two faunas, *Rhabdostichus* cf. *R. pulex* occurs just above the horizon of abundant *Eleutherokomma-Allanaria* spiriferid brachiopods, which forms apparently another widespread and stratigraphically consistent faunal zone in the very lowest Duperow and uppermost Souris River formations.

The general occurrence of these two faunas is useful in ascertaining the exact age of the basal Devonian reddish clastics around the edges of the basin. In Meade, Ziebach, and Armstrong counties, central South Dakota, and in Bighorn, Powder River, Carbon, and Carter counties, south-central Montana, the basal Devonian beds are probably of Duperow age. In Potter County, South Dakota, toward the edge of the Duperow, the *Rhabdostichus* fauna occurs within a few feet of the base of the Devonian. Northward, toward the North Dakota boundary, the basal Devonian clastic beds lie considerably below the *Rhabdostichus* fauna and are of Souris River age. Similarly, in northern Gallatin County, Montana, at the type Jefferson section at Logan, the presence of *Rhabdostichus* at the base of the Jefferson section (Wilson, 1955, p. 75), indicates that very probably only about 20–40 feet of basal silty dolomite are older than Duperow.

The eastern United States occurrence of *Rhabdostichus pulex* is at Miles Gulch near Hopewell, Ontario County, New York, in Middle Devonian strata of the Hamilton group. In Canada and in the Williston basin it occurs in strata considered Upper Devonian; these are separated from *Stringocephalus* bearing beds by a widespread unconformity. This emphasizes the correlation problem existing between the western and eastern Devonian faunal provinces of the United States. It is apparently not yet clear to what part of the western section the uppermost Hamilton (Tully fauna) corresponds, or where the important Upper-Middle Devonian unconformity of the western sections falls within the New York sequence.

3, Rhabdostichus cf. *R. pulex*, right valve, ×40, showing near centered beak, samples from Deep Rock No. 1 Bruisch, depth 9990–10,000 feet.

4,5, Rhabdostichus pulex (Clarke), right valves, ×50, from Hamilton group, at Miles Gulch, Hopewell, Ontario County, New York.

6,8, Rhabdostichus cf. *R. pulex* (Clarke), right valves, ×17 and ×15 respectively, showing strongly eccentric beaks, core from Shell No. 1 Veal, depth 6753½ feet.

7, Rhabdostichus cf. *R. pulex*, view of dorsal hinge line of interval mold of specimen with valves articulated, ×26, core from Shell No. 1 Veal, depth 6753½ feet.

9, Rhabdostichus cf. *R. pulex*, cluster of large right and left valves, ×17, core from Shell No. 1 Veal, depth 6753½ feet.

TABLE 1—OCCURRENCES OF *Rhabdostichus* IN WILLISTON BASIN DEVONIAN

Well or Outcrop	Depth	Feet above Souris River Formation	Occurrence in Duperow Formation and Feet above *Eleutherokomma-Allanaria* Zone
DAKOTA SHELF			
1. Shell 1 Winter, Corson County, South Dakota	6,600–6,650	50 to 100	Base of Upper Duperow
2. Shell 1 Veal, Perkins County, South Dakota	6,740	40	Lower Duperow, .25 ft. above brachiopods
3. Shell 1 Homme, Perkins County, South Dakota	7,510–7,520	40 to 50	Lower Duperow
4. Youngblood 1 Draskovitch, Corson County, South Dakota	6,155–6,165	65 to 75	Lower Duperow
5. Youngblood 1 Galvin, Dewey County, South Dakota	5,115–5,120	80 to 85	Lower Duperow
6. Dakota-Texas Co. 1 Thompson, Potter County, South Dakota	3,210–20	Basal Devonian is Duperow	Lower Duperow
7. Continental 1 Leuth, Wells County, North Dakota	4,400	75	Lower Duperow, .5 ft. above brachiopods
8. Continental 1 Dronen, Burleigh County, North Dakota	4,580	50	Lower Duperow
9. Continental 1 McCay, Burleigh County, North Dakota	4,585–4,600	30 to 55	Lower Duperow
10. Youngblood 1 Kelstrom, Grant County, North Dakota	5,815–5,875	10 to 70	Lower Duperow
11. Deep Rock 1 Brusich, Slope County, North Dakota	10,000	50	Lower Duperow
12. Amerada 1 May Billings, County, North Dakota	10,950	60	Lower Duperow
INNER BASIN			
13. Wanette 1 Lee, Ward County, North Dakota	7,610–7,620	160–170 below top of Souris River, picked from cave?	? in Souris River
14. Amerada 1 Iverson, Williams County, North Dakota	10,490 ··	100	Lower Duperow, .30 ft. above brachiopods
15. Shell 1 NPRR (Richey), Dawson County, Montana	8,830 & 8,900	230 and 300	Upper Duperow
16. Souris Valley 1 Moore, southwestern Manitoba	4,600–4,620	150–170	Lower Duperow
17. Norcanols 1 Ogema, southcentral Saskatchewan	6,810	20	Lower Duperow (occurrence unverified by writer)
21. Hunt 1 Lindquist, Daniels County, Montana	8,585–8,589	5	Lower Duperow
22. Mobil Producing 1 Birdbear, Dunn County, North Dakota	10,680	90	Lower Duperow
ROCKY MOUNTAIN OUTCROPS			
18. Type Jefferson section, Logan, Gallatin County, Montana	22 ft. above base of section	less than 20	Lower Duperow
19. Big George Gulch, Gibson Reservoir, Sawtooth Range, Teton County, Montana	380 ft. above base of section	330	Lower Duperow, .300 ft. above brachiopod zone
20. Hummingbird Creek, HN 587, T. 36N, R. 15 W5, Canadian Rockies, Alberta		approximately 100	Lower Fairholm, 120 ft. above base of Perdrix, about same distance above *Spirifer jasperensis* zone

REFERENCES

ANDRICHUK, J. M., 1951, Regional stratigraphic analysis of Devonian system in Wyoming, Montana, southern Saskatchewan: Bull. Amer. Assoc. Petrol. Geol., vol. 35, no. 11, p. 2368–2408.

BAILLIE, A. D., 1953, Devonian system of the Williston Basin area: Montana Department of Mines & Natural Resources Mines Branch, Publ. 49–2, p. 1–72.

BASSLER, R. S., & KELLETT, BETTY, 1934, Bibliographic Index of Paleozoic Ostracoda: Geol. Soc. Amer., Spec. Paper, No. 1.

LEVINSON, S. A. 1951, Thin sections of Paleozoic Ostracoda and their bearing on taxonomy and morphology: Jour. Paleont., vol. 25, p. 553–561.

RAYMOND, P. E., 1946, The genera of fossil conchostraca—an order of bivalved Crustacean: Bull. Mus. Comp. Zool., Harvard, vol. 96, no. 3, p. 221–276.

SHROCK, R. R., & TWENHOFEL, W. H., 1953, Principles of Invertebrate Paleontology: McGraw-Hill, p. 816.

WICKENDEN, R. T. D., & PRICE, L. L., 1952, The Mesozoic and Paleozoic formations of south-central Saskatchewan as encountered in the Norcanols Ogema No. 1 Well: Geol. Surv. Can. Paper 52–29, p. 55.

WILSON, J. L., 1955, Devonian correlations in northwestern Montana: Billings Geol. Soc. Guidebook, Sixth Annual Field Conference, p. 70–77.

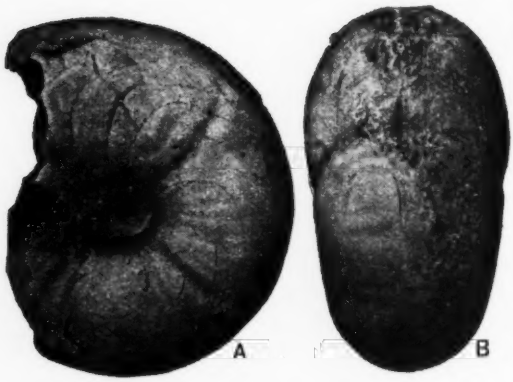
IMITOCERAS FROM THE EXSHAW FORMATION OF ALBERTA

CHARLES B. PAMENTER
McMaster University, Hamilton, Canada

The widespread black Exshaw shale is particularly well-known to Alberta stratigraphers because of its controversial relationship to the Devonian-Mississippian boundary. It was originally considered as part of the lower Banff shales of McConnell (1887), later called the Banff formation of Mississippian age by Shimer (1926). In 1937 Warren collected fossils from the lowest member of this formation, and principally on the tentative identification by Miller of *Tornoceras* cf. *T. uniangulare* (Conrad), he assigned the black shale to the Upper Devonian, naming it the Exshaw formation. Miller in 1938 described these goniatites, stressing their crushed condition and poor preservation and the resultant uncertainty of identification. In succeeding years numerous published field reports emphasized the lithologic similarities of the Exshaw to the overlying Banff, and the dissimilarities of both to the underlying Devonian Palliser formation, but opinions were rarely expressed in print as to the age relationships. Then, in 1952, Crickmay suggested that the Exshaw shale be returned to the Mississippian system (Kinderhook series), on the basis of zonal studies of brachiopods, lithology, and especially the identification of some Exshaw goniatites as "*Aganides* sp. close to *A. discoidalis* Smith." Supporting evidence for this suggestion is now accumulating.

During the 1955 field season, R. V. Best, working for the Shell Oil Company, discovered a pyritic siltstone lens with numerous fossils in the Exshaw formation near the Brazeau, River, Jasper Park, Alberta. Over sixty pounds of samples were collected and later turned over to the author for study at McMaster University. The samples are proving to be laden with conodonts and small pyritized goniatites, pelecypods, gastropods, ostracodes, brachiopods, crinoids, fragmentary vertebrates, etc. The extraction and identification of the fauna from this extremely dense rock is still in progress, and the results will eventually be available in the form of a thesis. The discovery of *Imitoceras* in the rock samples, however, appears to be of particular importance, so this account is being released before the completion of the thesis study.

In addition to several small immature goniatites of uncertain affinities, the available collections contain an internal mold about 10 mm. in diameter (Text-fig. 1). It is septate throughout. The shape of its external suture is shown by Text-figure 2. Only the general nature of the internal suture can be ascertained. It consists of a dorsal lobe with a single internal lateral lobe on either side of it. The umbilicus is small but not closed. The surface of the specimen bears a few sinuous transverse constrictions and

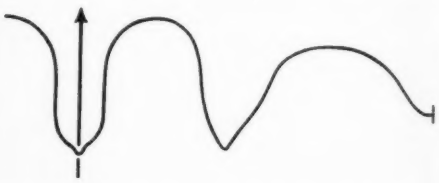


TEXT-FIG. 1—*Imitoceras* aff. *I. discoidale* (Smith) from a pyritized siltstone lens near the top of the Exshaw shale on the southwestern side of the Brazeau River opposite Mount Arête, Jasper Park, Alberta (coordinates 52°26′N., 116° 55′W.), ×5. McMaster Univ., Cat. No. N101-Cm. Photographs retouched by Frederick Leach.

rather prominent growth increments, which form lateral and ventral sinuses.

Presumably this specimen represents rather early growth stages of the large goniatites which are abundant in the Exshaw. Some of them attain a diameter of as much as 100 mm., but none reveals more than a portion of the sutures. The closed umbilicus of the large specimens probably represents a fully mature character.

Drs. A. K. Miller and W. M. Furnish compared this specimen with other goniatites from the Exshaw. They conclude that it is congeneric (but not conspecific) with *Imitoceras discoidale* (Smith) of the Kinderhook of Missouri and possibly Iowa, and that it is distinct from *Tornoceras*. In North America the genus *Imitoceras* has not been reported from rocks older than the Mississippian, though it is known from the Upper Devonian of the Eastern Hemisphere (Miller & Collinson, 1951, p. 460).



TEXT-FIG. 2—*Imitoceras* aff. *I. discoidale* (Smith). An external suture of the specimen illustrated by Text-figure 1, at a diameter of 9 mm., ×7.

The writer is indebted to the Shell Oil Company for making this study possible.

REFERENCES

CRICKMAY, C. H., 1952, Discrimination of late Upper Devonian: Jour. Paleont., vol. 26, p. 585–609, pl. 70–78.

MCCONNELL, R. G., 1887, Report on the geological structure of a portion of the Rocky Mountains . . . : Canada Geol. Surv., Ann. Rept., n. ser., vol. 2, pt. D, 41 p., 1 pl.

MILLER, A. K., 1938, Devonian ammonoids of America: Geol. Soc. Amer., Spec. Paper 14, 262 p., 39 pl.

——, & COLLINSON, CHARLES, 1951, Lower Mississippian ammonoids of Missouri: Jour. Paleont., vol. 25, p. 454–487, pl. 68–71.

SHIMER, H. W., 1926, Upper Palaeozoic fauna of the Lake Minnewanka section, near Banff, Alberta: Canada Geol. Surv., Bull. 42, p. 1–84, pl. 1–8.

SMITH, J. P., 1903, The Carboniferous ammonoids of America: U. S. Geol. Surv., Mon. 42, 211 p., 29 pl.

WARREN, P. S., 1937, Age of the Exshaw shale in the Canadian Rockies: Amer. Jour. Sci., vol. 233, p. 454–457.

HOW MANY FOSSIL SPECIES?

CURT TEICHERT
U. S. Geological Survey, Denver, Colorado

G. G. Simpson (1952) and A. Cailleux (1954) have attempted to guess the total number of species, animal and plant, which may have lived from the beginning of life on earth until the present day. Simpson guessed at something between 50,000,000 and 4,000,000,000 giving 500,000,000 as a possible approximation. Cailleux, taking into consideration his theory of the geometric expansion of life during geologic time (Cailleux 1950, 1952), reduced these estimates to a figure between 17,000,000 and 860,000,000. There seems little ground, however, for his expressed hope that paleontologists may expect ever to know all these species, because these figures include Bacteria, Fungi, Protozoa of various kinds, worms, and a host of other groups which leave few or no preservable traces in the rocks and whose history we shall, therefore, never be able to check fully.

A question of somewhat more practical interest, however, is that of the possible number of *fossil* species, that is, those which we may actually expect to find entombed in the rocks. I have been interested in this question for many years. I have approached it on the basis of several different premises and have always obtained figures that were of the same order of magnitude.

Our starting point must be: How many species exist today whose remains are "fossilizable"? In Table I are listed estimates of the number of known species of all important invertebrate groups whose members have hard covers or skeletons, and which are therefore "fossilizable." These will be of principal use to paleontologists of the future though "unfossilizable" ones that happen to get preserved may sometimes be of greatest interest. The figures for total numbers of living species are a compromise of published estimates by Hesse (1929), Schilder (1949), and Mayr, Linsley & Usinger (1953). The numbers of fossilizable species are little more than guesses, but they should indicate the order of magnitude.

TABLE I

	Total known species	Fossilizable species
Protozoa		
Sarcodina	10,000	10,000
Porifera	4,500	4,000
Coelenterata		
Anthozoa	6,110	5,500
Hydrozoa	2,700	1,000
Bryozoa	3,300	3,000
Mollusca	125,000	120,000
Arthropoda		
Crustacea	25,000	20,000
Echinodermata	4,200	4,200
Total	180,800	169,700

The number of potentially fossilizable noncrustacean arthropods, though very large, is meaningless for our inquiry. There are between 750,000 and 850,000 species of insects alone, but this group has probably risen to its present peak since the expansive development of the angiosperms in the Late Cretaceous. The distribution of insects in rocks is extremely haphazard and it is quite certain that we shall never find the remains of all insect species that ever lived. The same is true for the Arachnoidea and several smaller classes of arthropods.

Schilder (1949), Cailleux (1954), and Mayr, Linsley & Usinger (1953) assume that about one-half of the number of existing species has been scientifically described and named, but it is more than likely that most of the undescribed species will be either insects, or else small, soft-bodied animals and that the percentage of known shell- and skeleton-bearing species is much greater. We may be near the truth, or perhaps err on the optimistic side, if we accept 250,000 as the number of living invertebrate species which are of such a kind and exist under such conditions that their hard parts become easily and normally enclosed in marine or lacustrine sediments. I have no reliable figure for fossilizable annelids, but they may well be included in this generous estimate.

In the Java Sea, according to Martin (1919), no mollusks belonging to still-living species existed in early Miocene time; in Australian waters the first examples of still-

living species of mollusks appeared in the beginning of the Pliocene, about 12 million years ago (Singleton 1941). The period of time required for a complete renewal of a marine molluscan fauna in a given area would thus appear to be 12 to 20 million years. Schilder (1949) used 15 million years, but since a number of short-lived species appeared and became extinct during such an interval, the lower figure of 12 million years may give more accurate results in extrapolation.

Assuming, then, that this figure is also true for non-molluscan faunas and assuming, further, that the number of contemporaneous species at any one time in the past was about the same as now, we would arrive at a total of 11,250,000 fossilizable invertebrate species (exclusive of insects) for the time since the beginning of the Cambrian. This figure is almost certainly too large, because the number of contemporaneous skeleton- or shell-bearing species in some past periods, for example the Cambrian and the Triassic, was most probably smaller than now.

In 1950, Cailleux suggested that animal life may have expanded geometrically throughout geological time in such a way that the number of animal species doubled approximately every 80 million years. In 1952, Cailleux made a similar calculation for plants. In both cases only a few samples were used (five faunas in 1950, eight floras in 1952) and it seems to me that a great many more statistical studies on the abundance of species in faunas and floras of all ages and from many areas will be required before the law of the "expanding life" can be more accurately formulated. For example, considering the abundance and variety of life in the Late Cretaceous, one might find it difficult to believe that the number of species at that time should have been only half that of the present day. It is even more difficult to conceive of an indefinite continuance of this geometric expansion of life in future eons. Cailleux's formula, according to whether one would take 8 or 12 million years as figures for a complete faunistic cycle, would lead to an estimate of between 3,000,000 and 5,000,000 fossilizable marine species for the entire geologic record, but Schilder (1949) gave an estimate of a possible 5,000,000 for the mollusks alone. Equally unlikely, however, would be to assume that the number of fossilizable species has been constant since the Cambrian. This would give us a total of 11,250,000 species. Obviously, there are more fossil species in the Ordovician than in the Cambrian, but already in the Ordovician the occupation of various biotopes by shell- and skeleton-bearing animals had progressed to a point that from then on the increase in the number of such species has probably slowed down.

The true figure for the total number of fossilizable invertebrate species, and, therefore, of fossil invertebrate species waiting to be collected and described, may be somewhere in the vicinity of 7 or 8 million.

It remains to form a quick estimate of possible figures for vertebrates and plants. Numbers of living vertebrate species are as follows:

Fishes	20,000
Amphibia	2,800
Reptiles	5,500
Birds	8,600
Mammals	13,000
Total	48,900

In what kind of progression various groups of vertebrates have increased (and decreased) would make an interesting study. We may neglect the birds whose complete history we shall never know. Mammals appeared so late that the total number of their species can be assumed to be small, perhaps not more than 100,000, in spite of the shorter survival time of the species. Altogether the total number of extinct vertebrate species, almost all of which would have been fossilizable, is probably not more than one million.

Of vascular plants there are now about 350,000 species (Cailleux, 1953), of others (which are mostly nonfossilizable) 25,000. But the number of vascular plant species must have risen abruptly with the advent of the angiosperms. Estimates of total number of past plant species are, therefore, very difficult to make; also, because of hazards of hazards of preservation, a large percentage was probably never fossilized.

Thus, there are probably good reasons for believing that about 10 million may be the maximum number of fossil species which

paleontologists of future generations will be called on to describe and that about three-fourths of these will be marine invertebrates, useful and needed in stratigraphic correlation. This number is at least 20, perhaps 50 times as many as the number of fossil species now known to science, but it is slightly less discouraging than Simpson's maximum of 4 billion.

In conclusion, one may feel tempted to quote, somewhat irreverently, from Mark Twain's *Life on the Mississippi:* "There is something fascinating about science. One gets such wholesale returns of conjecture out of such a trifling investment of fact." However, there is also a serious message if we look at the task ahead: first, to paleontologists, to put their house in order by organizing their knowledge as well as their taxonomic methods and procedures; second, to organizations which are responsible for the promotion of scientific knowledge, to employ more paleontologists and encourage them to engage in down-to-earth monographic work. This is probably the last time in the history of science that an undertaking such as the *Treatise on Invertebrate Paleontology* can be carried through with the unrewarded labor of love of 120 individual paleontologists. The next time such an organization of knowledge becomes necessary, the wholehearted and official support of geological organizations throughout the world will be required.

REFERENCES

CAILLEUX, A., 1950, Progression géométrique du nombre des espèces et vie en expansion: C. R. Soc. Géol. France, p. 222–224.

——, 1952, Richesse des flores, physiologie et évolution: Colloques Intern. Centre Nation. Rech. Scient., XLI, Evolution et phylogénie chez les Végétaux. Paris, p. 238–241.

——, 1953, Biogéographie mondiale: "Que Sais-je?" Press. Univ. France, 126 p.

——, 1954, How many species?: Evolution, vol. 8, p. 82–83.

HESSE, R., 1929, Bericht über das "Tierreich": Sitz.-Ber. Preuss. Ak. Wiss., Phys.-math. Kl., p. XL–XLIII.

MARTIN, K., 1919, Unsere palaeozoologische kenntnis von Java: Leiden, 158 p., 4 pl.

MAYR, E., LINSLEY, E. G., & USINGER, R. L., 1953, Methods and principles of systematic zoology: vii+328 p, McGraw-Hill.

MOORE, R. C., 1955, Invertebrates and geologic time scale; *in* Poldervaart, Crust of the Earth: Geol. Soc. Amer., Spec. Pap. 62, p. 547–574.

SCHILDER, F. A., 1949, Statistical notes on Malacology: Malac. Soc. London, Proc., vol. 27 (1946–49), p. 259–261.

SIMPSON, G. G., 1952, How many species?: Evolution, vol. 6, p. 342.

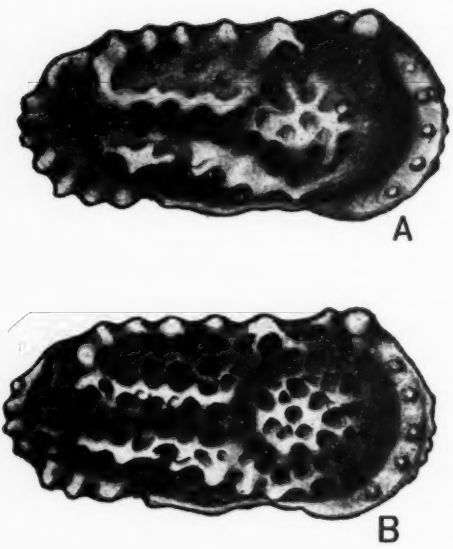
SINGLETON, F. A., 1941, The Tertiary geology of Australia: Roy. Soc. Victoria, Proc., vol. 53, Pt. 1 (N.S.), p. 1–125, 3 pl.

THE USE OF FOOD COLORING AS A NEW TECHNIQUE FOR STAINING MICROFOSSILS

R. L. ARTUSY AND J. C. ARTUSY
Fort Worth, Texas

During recent years the paleontologist has become more cognizant of details of structure and ornamentation of fossil forms and has been confronted with the difficult task of studying, identifying, and describing microfossil shells. This is especially true among the more ornate types of ostracodes in which the maze of minute detail present in the interior or exterior of the valve has made the separation and identification of numerous genera and species very difficult. The ostracode family, Cytheridae, which occurs abundantly in most marine Tertiary beds, and includes numerous diagnostic zone fossils, possesses an unusually high percentage of such ornate representatives. During a comprehensive study of Claiborne ostracodes, it became necessary to develop a new method of bringing forth surficial detail of ornate specimens of this and other families, while not permanently altering or destroying surface features of the type specimens. Green food coloring stain was found to give results superior to that of other types of coloring or staining agents.

Ordinarily, the paleontologist or artist, working with the binocular microscope and occupied with the study of microscopic fossils, sees only specimens which generally lack sufficient contrast to yield adequate de-



TEXT-FIG. 1—Ostracode specimen before staining (*A*) and after (*B*).

tail for figuring; very small protuberances, reticulate patterns, and denticulations, when present, are seldom clearly visible. To obtain sufficient contrast, it has been necessary to alter the appearance of the fossil to bring forth its true characters. In the past this has often been achieved by the application of various inks, artificial stains, and etching processes, none of which were satisfactory.

After much experimentation using specimens of the genus *Actinocythereis*, one of the most ornate members of the ostracode family Cytheridae, excellent results were obtained by using food coloring stains applied to the shell. Considerable detail previously concealed was immediately brought forth by the utilization of such coloring agents. Although various colors of food coloring stains were tried (yellow, red, blue, and green), only the green stain was found capable of adequately bringing out the desired contrast.

In utilizing such food coloring stains, best results were obtained when first a few drops of the coloring solution was poured into a small cup or cap and the residue concentrated by evaporation. After desiccation, a moist sable 00 brush was dipped into the concentrated green residue and then applied directly to the microfossil. The green food color tends to drain downward, concentrating in the deeper areas where every depression, reticulation and pit is delineated as a darker shade of green. As a result, high areas stood forth in bold relief accented as lighter shades of green.

When such coloring solutions were applied to the specimen, the liquid immediately dried due to the normal heat of the microscope lamp. After the stain was completely dry, every minute detail of the carapace was delineated and each spine, knob, boss, reticulation, the details of hinge structure and other surface features became visible.

One coating of this liquid generally is sufficient to color completely the interior or exterior of even the largest ostracode valve or hinge area. After completing the examination of the stained specimen, the green food coloring may readily be removed by washing the shell with water.

In many cases, after application of the green stain, so much detail is brought forth that often the stained specimens even fail to resemble unstained forms. In fact, the stained and unstained specimens, when being directly compared, often appear so dissimilar that they may not be recognized as identical species. To illustrate this point, Text-figure 1-*A* is a drawing of a specimen before staining, and 1-*B* represents the same specimen after staining.

When utilizing such stains it was found that many of the brands of food coloring did not yield the desired results. The stain marketed under the label of Crown Colony Food Color was found to be the most satisfactory.

It should be pointed out that this same technique may also be used to bring out additional surficial details on many of the more ornate forms of Foraminifera, Radiolaria, Chitinozoa, and numerous other microfossils.

SEPARATION OF INTERAMBULACRAL COLUMNS FROM THE APICAL SYSTEM IN THE ECHINOIDEA

PORTER M. KIER
Avonmore, Pennsylvania

In my description of *Palaeechinus canadensis* (1953, p. 66–67) I reported that one of the interambulacral columns did not come in contact with an ocular. Jackson (1912, p. 334) stated "I have found so generally in Paleozoic and later Echini that ocular plates cover the ambulacra and laterally the interambulacra on either side, that I think the lack of this latter character in the specimen here described may be due to displacement in fossilization." However, it was clear in this specimen that no such displacement had occurred. Later I noticed this separation in some specimens of *Linthia somaliensis* Currie and decided to investigate the condition and determine whether or not it was of any significance. Much to my surprise I found many specimens with this condition. A study of illustrations of fossil and Recent echinoids revealed over 30 specimens which did not have their oculars in contact with the youngest interambulacral plate. Furthermore, I examined specimens of *Linthia cavernosa* and *Encope emarginata* in the British Museum, and *Lutetiaster maccagnoi*, *Eupatagus cairensis*, *Arcaechinus auraduensis* and *Opissaster derasmoi* in the Somaliland Collection in the Sedgwick Museum, Cambridge, in which an interambulacral column was isolated from its ocular.

In my paper I further stated that "more interambulacral plates could still be produced in the ocular area and by resorption of part of the genital and adjacent ambulacral plates these new plates could move ventrally." Although this is a possibility, in some cases it can be shown that no more plates are added after this separation of ocular from interambulacrum. This fact is shown clearly in a study of the development of *Echinocardium cordatum* (Pennant), *Micraster coranguinum* (Leske), and *Linthia somaliensis* Currie.

Echinocardium cordatum (Pennant)

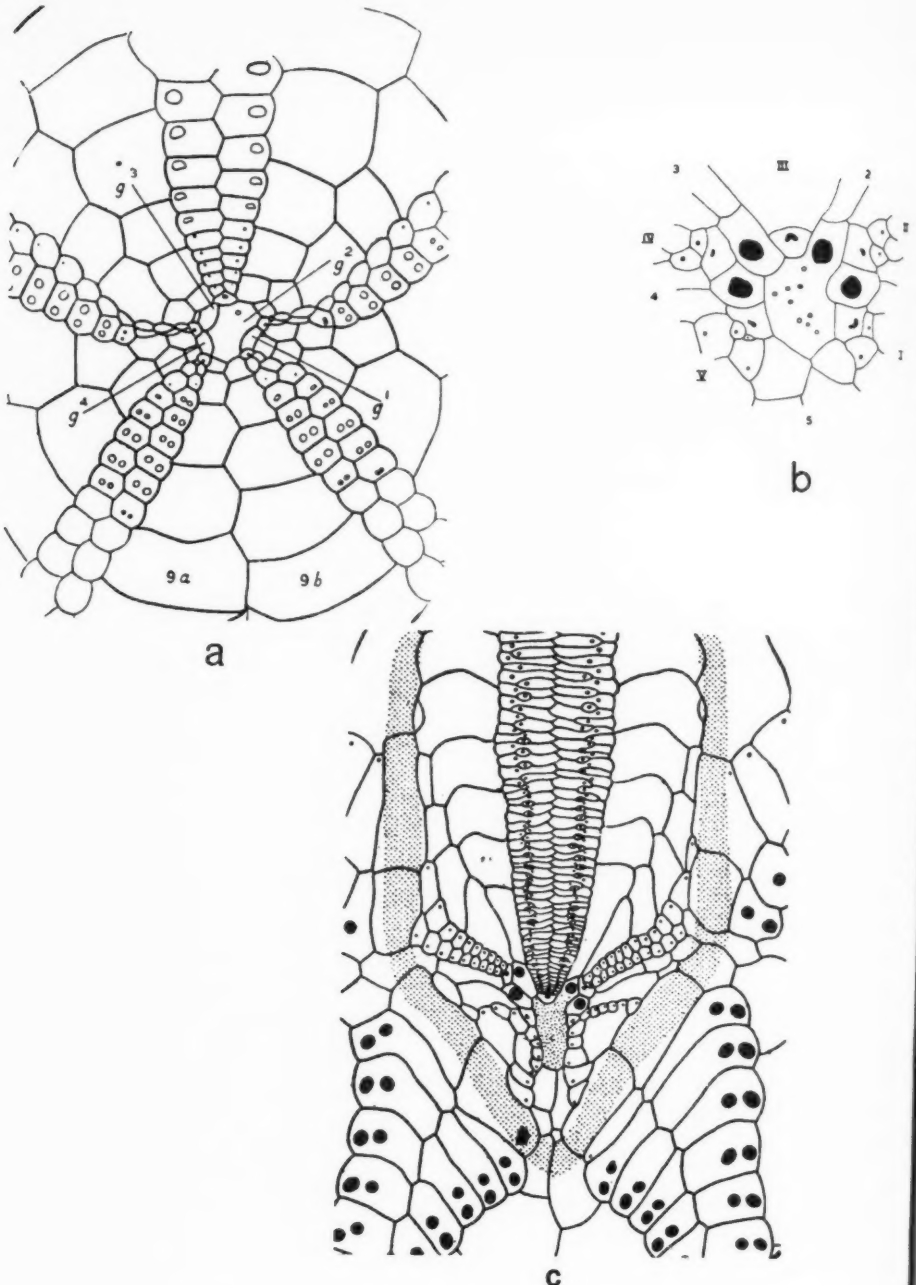
In the young of *Echinocardium cordatum* all the interambulacral columns are in contact with their respective oculars (Text-fig. 1a). The figured specimen was 5.5 mm. long and both Gordon (1926b, p. 282) and Hawkins (1913, p. 176) state that no more coronal plates, other than those for the anterior ambulacrum, are added after this stage. The test grows by an increase in the size of the plates already developed. In specimens only 18–21 mm. long, which were kindly sent to me by Dr. Vevers of the Plymouth Marine Biological Station, columns 2b and 3a are already separated from their oculars (Text-fig. 1b). In an adult, (Text-fig. 1c) columns 2b,3a,5a,5b, and 1a are separated from their oculars.

Micraster coranguinum (Leske)

Through the courtesy of A. G. Brighton, I was able to examine a large number of well-preserved specimens of *Micraster coranguinum* from the Upper Chalk of England. There were thirty specimens in which the apical system was well enough preserved to see whether or not the last interambulacral plates were in contact with oculars. Of these thirty specimens only three of them had an interambulacrum separated from its ocular and in each case it was interambulacrum 4b. These three (Text-fig. 2b) were the largest specimens in the group (65 mm. long). No more plates were being produced in this area as shown by the fact that specimens only 45 mm. long had the same number of plates in interambulacrum (4b) as the three largest specimens.

Linthia somaliensis Currie

Among 68 specimens of *Linthia somaliensis*, from the Lower Eocene of British Somaliland, in which it was possible to see the plates of the apical system, only the smallest one (Text-fig. 3a), 18.5 mm. long, had all its oculars in contact with interambulacral columns. In all the larger specimens, ocular III is separated from columns 2b and 3a (Text-fig. 3b). Again in this species, as in the previous two, no more interambulacral plates are produced in these isolated columns. The

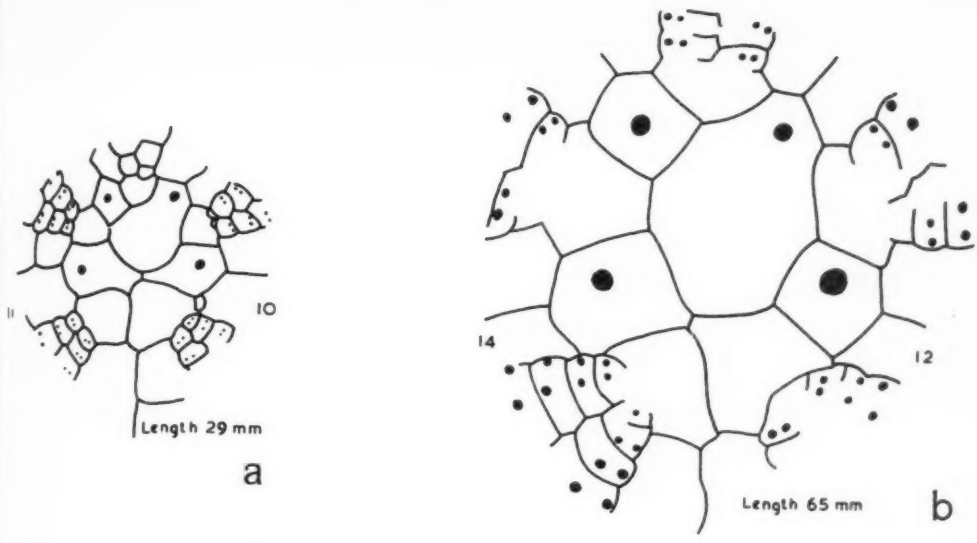


TEXT-FIG. *1*—*Echinocardium cordatum* (Pennant).

a, Aboral view of a young specimen, 5.5 mm. long, showing all its interambulacral columns in contact with oculars (From Gordon, 1926, p. 283, fig. 14), ×21.

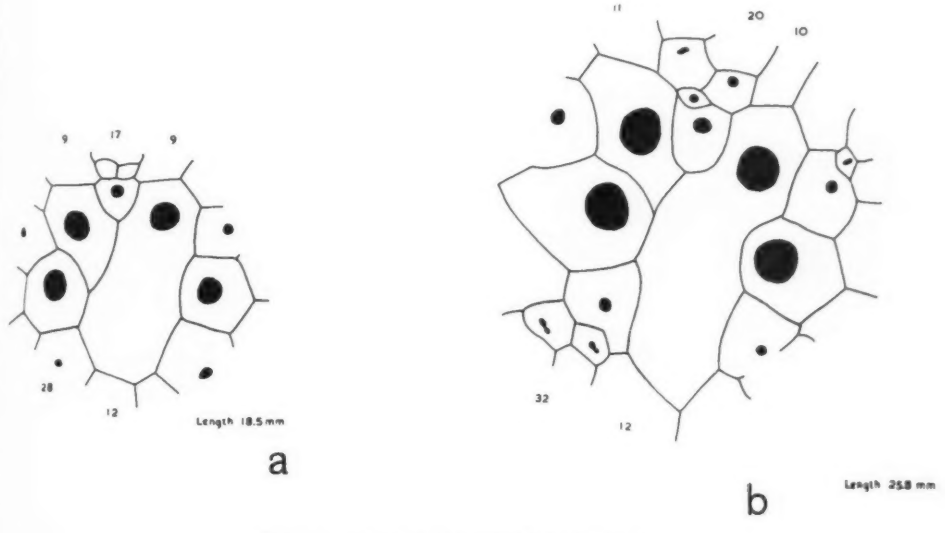
b, Aboral view of the apical system of a specimen 18.9 mm. long, with columns 2b and 3a isolated from their ocular.

c, Aboral view of an adult specimen showing columns 2b, 3a, 5a, 5b, and 1a isolated from their oculars (From Hawkins, 1920, pl. 69, fig. 4).



TEXT-FIG. 2—*Micraster coranguinum* (Leske).

a, Apical system of a young specimen (B2155, Sedgwick Museum) 29 mm. long, in which all the interambulacral columns are in contact with oculars.
b, Apical system of an adult specimen (B2490) 65 mm. long in which interambulacral column 4b is isolated from its ocular; ×8.



TEXT-FIG. 3—*Linthia somaliensis* Currie.

a, Apical system of a specimen (C13369, Sedgwick Museum) only 18.5 mm. long, in which all the interambulacral columns are in contact with their oculars.
b, Apical system of a large specimen (C13370) 25.8 mm. long, in which interambulacral columns 2b, 3a are not in contact with ocular III; ×14.

largest specimen, 44.4 mm. long, has no more plates in columns 2b and 3a than a specimen only 21.4 mm. long.

CONCLUSIONS

In most cases this separation of the oculars from the interambulacral columns seems to be due to an increase in the size of the adjacent ambulacral plates. At first I thought this separation might be caused by plate pressure due to the continuation of the production of ambulacral plates after the cessation of production of interambulacral plates. However, this does not appear to be the case. In *Echinocardium cordatum*, production of ambulacral plates for all the columns except the anterior ambulacrum ceases at about the same time that production of interambulacral plates stops. Regardless of this the interambulacral columns still separate from their oculars.

This cessation in the production of interambulacral plates seems to be a progressive feature in echinoids. As far as I know it seldoms occurs among the Regularia, Holectypoida, Cassiduloida, and Clypeastroida, but among the Spatangoida this cessation is very common if not normal.

REFERENCES

GORDON, I., 1926, The development of the calcareous test of *Echinocardium cordatum*: Phil. Trans., ser. B, vol. 215, p. 255–313, 27 text-fig.

HAWKINS, H., 1913, The anterior ambulacrum of *Echinocardium cordatum* Penn., and the origin of compound plates in echinoids: Proc. Zool. Soc. London., vol. 12, p. 169–181, pl. 26.

——, 1920, The morphology and evolution of the ambulacrum in the Echinoidea Holectypoida: Phil. Trans., ser. B., vol. 209, p. 377–480, pl. 61–69.

JACKSON, R. T., 1912, Phylogeny of the Echini, with a revision of Paleozoic species: Mem. Boston Soc. Nat. Hist., vol. 7, 491 p., 76 pl.

KIER, P. M. 1953, A new lower Caboniferous echinoid from North America. Geol. Mag., vol. 90, p. 65–69.

FAUNAS AND FACIES OF SOME MIDDLE MIOCENE DEPOSITS IN JAPAN

KARYU TSUDA

Geological Institute, Faculty of Science, Niigata University

INTRODUCTION

The Middle Miocene deposits in Japan have been so intensely influenced by tectonic disturbances, that it is very difficult to study the relationship between their faunas and facies. It seems, however, that the rocks were deposited during an early stage of the Miocene transgression. The sedimentary environments under such circumstances were variable, and the faunas and facies were effected by the varying conditions. In this paper, a few examples of the relations between the faunas and facies in the Japanese middle Miocene deposits, and the conditions of their sedimentary environments are discussed. One is Formation B in District Y and another Formation O of Island S.

The names of the formations and districts alphabetically represented in this article are as follows:

Formation A: Nirehara and Iwaine formations
Formation B: Kurosedani formation
Formation C: Joyama formation
Formation D: Otogawa formation
District Y: Yatsuo district
Formation O: Orito formation
Island S: Sado Island

ACKNOWLEDGMENTS

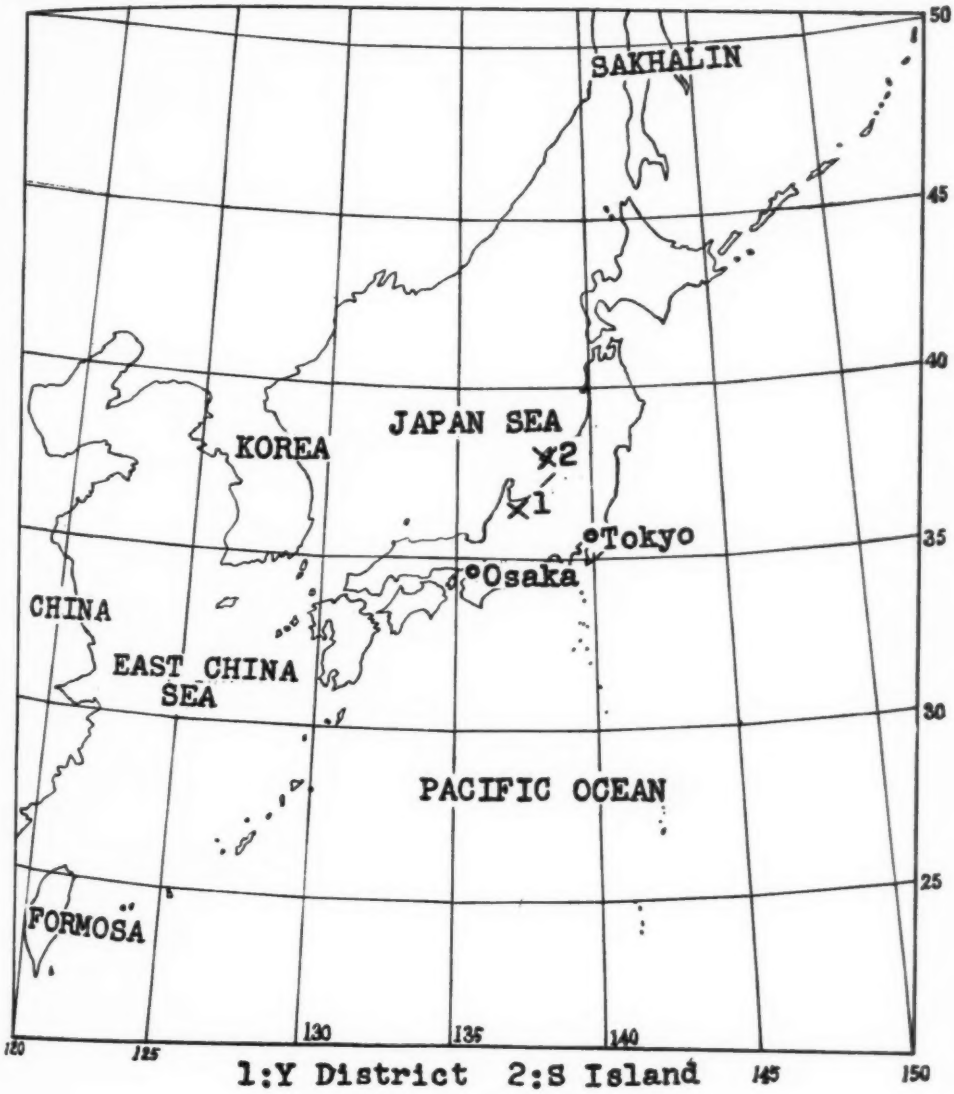
The writer wishes to express his thanks to Professors N. Ikebe of Osaka Municipal University, J. Makiyama of Kyoto University, S. Nishida of Niigata University, and the late Louis J. Wilbert, Jr., of Louisiana State University for their kind assistance and advice concerning this study.

STRATIGRAPHY

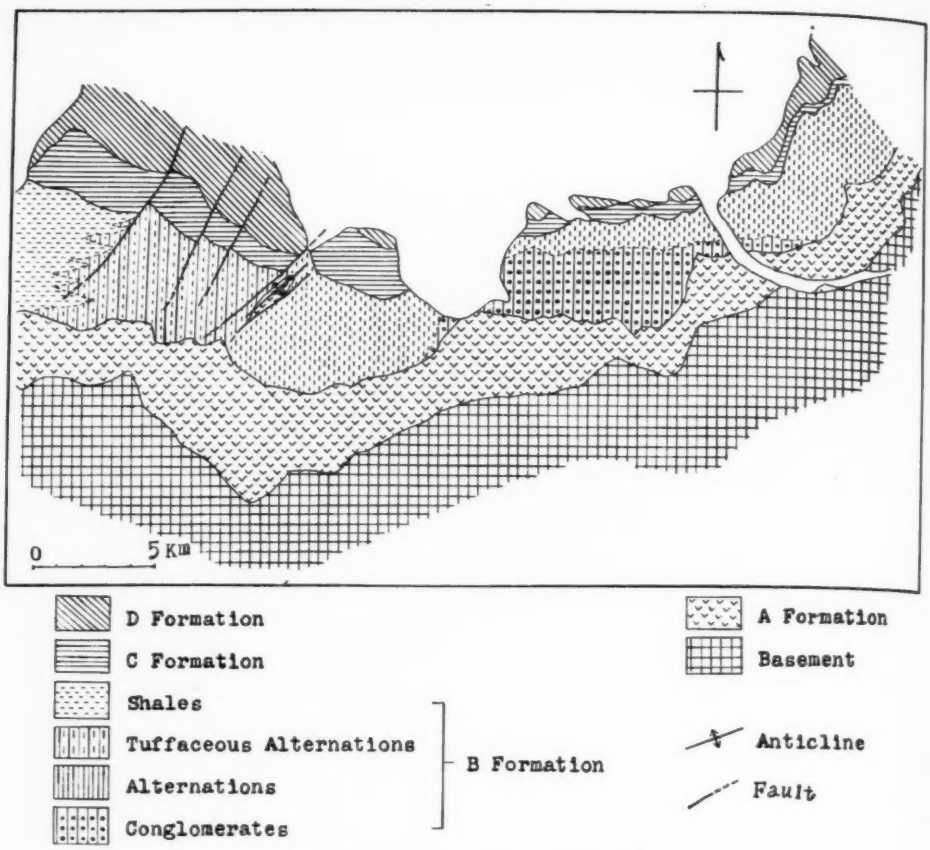
The Neogene deposits in District Y unconformably overlie granite and Mesozoic sediments. They form a monoclinal structure in the north, and have a general east west trend. The stratigraphy of this district is as follows:

Formation D	Upper Miocene
Formation C	
Formation B	Middle Miocene
Formation A	Lower Miocene
Basement	

Formation A, occupying the lower portion of the Neogene deposits, consists mainly of a thick series of volcanic products such as andesite lava flows, agglomerates, tuff breccias, and tuffs. The basal conglomerates are present in the lowest portion of this formation. There are some thin beds of lignite which contain fragmental plants. Formation B resting conformably on formation A is composed of conglomerates, sandstones, and shales. Formation B also contains abundant fossilized animals and plants. The rocks of this formation are varied and there is scarcely any persistent stratum. Formation C which rests conformably on formation B consists of homogeneous massive mudstones with poor fossilized animals and plants. For-



TEXT-FIG. 1—Index map.



TEXT-FIG. 2—Geologic map of District Y.

mation D, the uppermost one in this district, is composed mainly of sandstones and siltstones. It lies unconformably on Formation C.

As already mentioned, the rock facies of Formation B are very changeable. For example, a remarkable body of boulder conglomerates over 400 meters thick is present in the middle of Formation B. Near the top of the conglomerate body are alternating conglomerates and sandstones. The conglomerate body is cone-shaped. A triangular section of this cone is shown in Text-fig. 3. The conglomerates grade into conglomerate, sandstone, and siltstone outside the conical body. The alternating rocks are replaced by a shaly facies in the western area. Generally speaking, the contact of the cone-shaped body is ill-defined, inasmuch as the transformation of the conglomerate to the shaly mass takes place through alternating sand and shales and siltstones. T he vertical transition is similar to the lateral transition. In other words, the maximum grain size is in the lowest portion of the conglomerates and it decreases in all directions out from this maximum.

The occurrence of fossilized animals and plants in Formation B is varied and closely related to the facies variation. Because of this there is only one key bed which indicates a time plane, a tuff bed in the upper portion.

In the alternating sands and shales near the conglomerates, abundant fossil plants are present. *Comptoniphyllum naumanni* Nathorst, and *Liquidamber formosana* Hance are the most representative forms. Lignite beds, 30 to 70 cm. thick and driftwood are also very common. The conglomerates and the alternating sands and shales

near the conglomerate contain only terrestrial organic remains.

Abundant marine and terrestrial forms are present in the alternating sands and shales far away from the conglomerates. The terrestrial forms are the same as those present near the conglomerates, but it is significant that marine forms are present only in the rocks far away from the conglomerates. The characteristic marine forms are as follows:

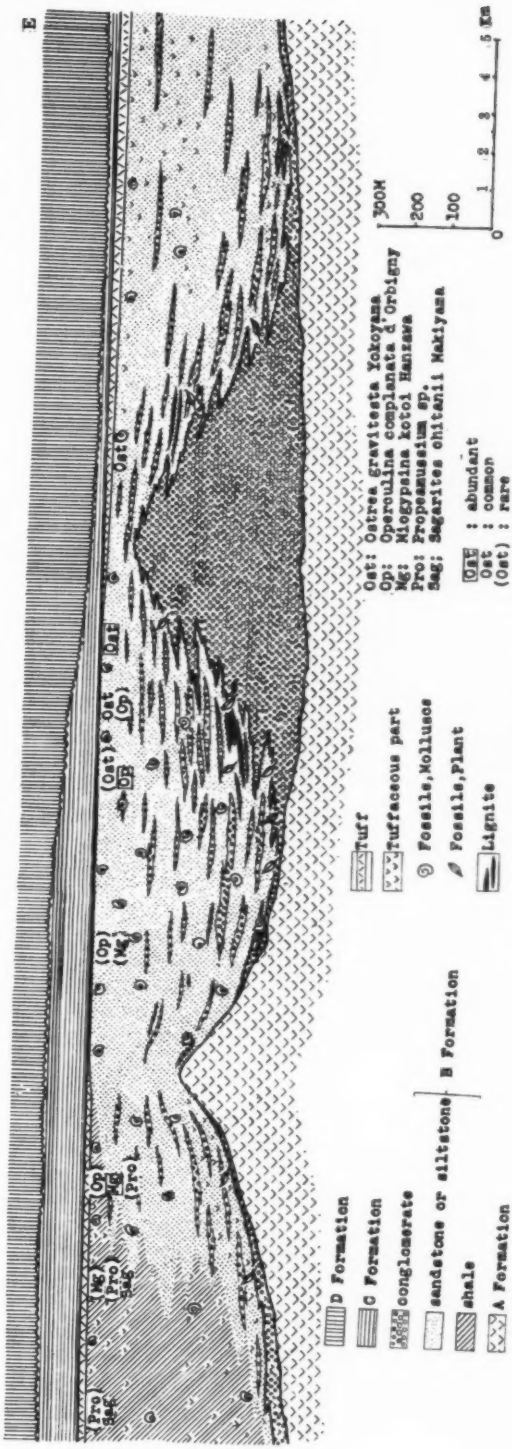
Protorotella yuantaniensis Makiyama
Littorinopsis miodelicatola Oyama
Cerithideopsilla, n. sp.
Vicaryella ishiiana (Yoloyama) var.
Vicarya yokoyamai Takeyama
Neverita coticazae Makiyama
Chicoreus liganouranus (Nomura)
Babylonia kokozurana Nomura
Anadara kakehataensis Hatai & Nishiyama
Anadara kurosedaniensis Hatai & Nishiyama
Ostrea gravitesta Yokoyama
Chlamys yanagawaensis Nomura & Zinbo
Geliona stachi Oyama
Geloina yamanei Oyama
Joanisiella takeyamai Otuka

Although more than half of these are extinct species, it seems plausible that the group of fossils represents a shallow brackish water environment.

There are also marine and terrestrial forms present in the alternating sands and shales farther away from the conglomerates, but they are not as abundant as in the rock nearer the conglomerates. Although the terrestrial forms are similar, the marine forms are slightly different. A barrier which is recognized as a Recent anticline, divided the sedimentary environments into eastern and western parts. The effect of the barrier is seen not only in the marine fauna, but also in the rock facies, *i.e.*, the alternating sands and shales are very tuffaceous in the western side, but not in the eastern. The representative marine forms are as follows:

Sagarites chitanii Makiyama
Protorotella yuantaniensis Makiyama
Vicaryella ishiiana (Yokoyama)
Dentalium sp.
Yoldia sp.
Anadra kakehataensis Hatai & Nishyiama
Propeamussium sp.
Cardium sp.
Cultellus izumoensis Yokoyama
Solemya tokunagai Yokoyama

Anadara kakenhataensis, Vicaryella ishiiana and *Protorotella yuantaniensis* are

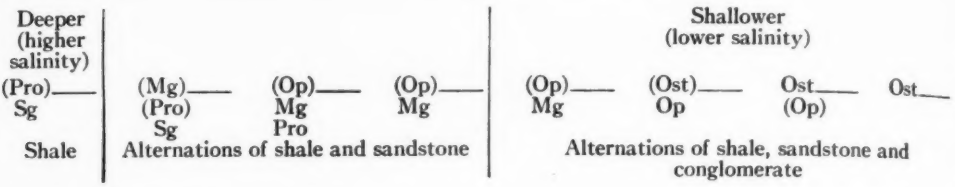


TEXT-FIG. 3—Stratigraphic diagram of District Y.

TABLE 1

Shales	Alternations	Alternations	Alternations	Conglomerates	Alternations	Alternations
(very tuffaceous)		(not so tuffaceous)			(very tuffaceous	
Mollusca	Mollusca Plants	Mollusca Plants	Plants Lignite Beds	Drift-wood	Plants Lignite Beds	Mollusca Plants
deeper water forms only	shallow water, deep water and terrestrial forms	brackish shallow water and terrestrial forms	terrestrial forms only			brackish shallow water and terrestrial forms

forms which lived in shallow and brackish waters, while *Sagarites chitanii*, *Propeamussium* sp. and *Solemya tokunagai* probably indicate a deeper sea of normal salinity. The fauna contains both of these infusible elements.



Ost = *Ostrea gravitesta* Yokoyama
Op = *Operculina complanata* d'Orbigny
Mg = *Miogypsina kotoi* Hanzawa
Pro = *Propeamussium* sp.
Sg = *Sagarites chitanii* Makiyama

The shales in the western area contain poor fossils. The common forms are:

Sagarites chitanii Makiyama
Yoldia sp.
Propeamussium sp.

These forms indicate a deeper sea of normal salinity. No brackish or shallow water forms are known.

The fossil occurrences are summarized in Table 1.

It is evident that the deposits vary from a terrestrial conglomeratic facies which contains only drift-wood fragments, to a marine shaly facies characterized by marine fossils chacteristic of a deep sea of normal salinity. The transitional rocks between the terrestrial conglomerates and marine shales contain brackish and shallow sea fossils mixed with terrestrial forms.

A few tuff beds in the uppermost part of Formation B extend over a large area without interruption and are useful key beds. These tuff beds are present in all the beds where the different faunas are present, and demonstrate that the faunas are contemporaneous. The faunas, then, are strongly effected by ecological conditions. The lateral changes of common species in the tuffs and the beds adjacent to the tuffs are shown in the following table:

Ostrea gravitesta, one of the typical brackish water forms, is abundant near the conglomerates in Formation B. *Ostrea gravitesta* becomes less abundant at greater distances from the conglomerates while other forms forms appear successively. This change indicates an increase of salinity and depth. It is very interesting that the habitation of *Operculina complanata* was not the same as that of *Miogypsina kotoi*, i.e., the former is more adapted for a lower salinity than the latter, while the suitable depth for both of them may be similar. *Operculina complanata* and *Miogypsina kotoi* are very common in the Japanese middle Miocene deposits. Often they occur together, but in such cases, if one is abundant, the other is rare, or they both may be rare. This is due to the ecological differences of the two species.

FORMATION O

Formation O in Island S consists mainly of sandstones and conglomerates, with

some interbedded limestones. The maximum thickness of this formation is less than 30 meters. Fossils are not as abundant and their preservation is not as good as in Formation B. Inasmuch as the geologic structure of Island S is complicated by faults and folds concealed underneath the young deposits, the distribution of Formation O is not continuous, although the rocks are exposed sporadically at places. The faunas indicate both ecological and sedimentary conditions. The fossil localities are shown in Text-fig. 5, and they may be classified into five groups showing the dominant species.

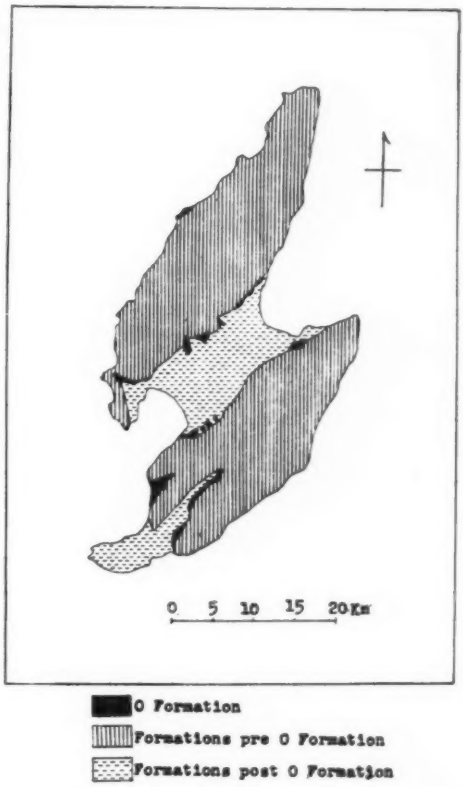
Group	Locality Number	Ost	Op	Mg	Other marine forms
I	1	v, a			
	2	a			c
	3	a			c
	4	a			c
II	5	r	r		c
III	6		va		c
	7		va		c
IV	12		C	va	a
V	8				c
	10				c
	11				c
	13				a

Ost = *Ostrea gravitesta* Yokoyama
Op = *Operculina complanata* d'Orbigny
Mg = *Miogypsina kotoi* Hanzawa
va = very abundant
a = abundant
c = common
r = rare

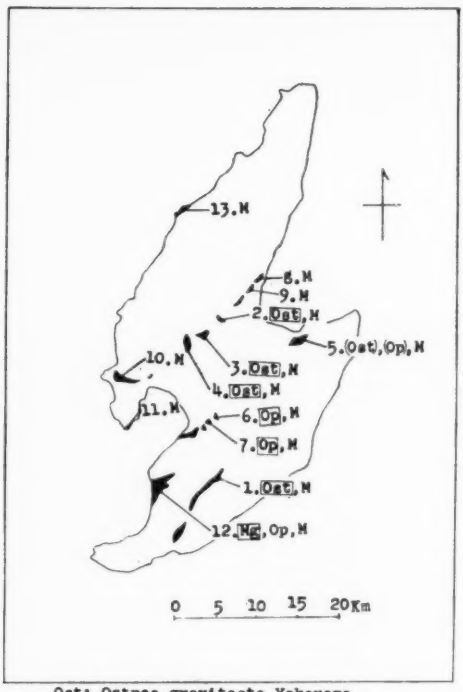
No deeper water forms such as *Sagarites chilanii* or *Propeamussium* sp. were discovered.

Group I contains many *Ostrea gravitesta*, and they make an ostrea bank in locality 1. Only one locality belongs to group II, which contains *Ostrea gravitesta* and *Operculina complanata* together. An abundances of *Operculina complanata* characterizes group III, in which no *Ostrea gravitesta* was discovered. In locality 12, which belongs to group IV, *Miogypsina kotoi* and *Operculina complanata* are rarely found in great abundance. Here some fragmental fossil limestones are formed. In the localities belonging to group V, there are abundant molluscs and some foraminifers, brachiopods and echinoids, but no characteristic forms are present.

The paleogeography of the O stage is indicated in Text-fig. 6. A strait existed in the O stage in the recent Island S and localities 2, 3, and 4 were situated in the inner portion of the strait where the water was strongly effected by influx of fresh water. At some disance from these localities to the Northeast and southwest, the strait changes to the open sea. Localities 5, 6, and 7 are situated in the transgressive portion where the salinity is higher than the inner portion, but lower than the open sea. Locality 8 may be in the open sea of normal salinity or near the coast. Locality 1 may be in a small embayment where the effect of the fresh water is very marked.



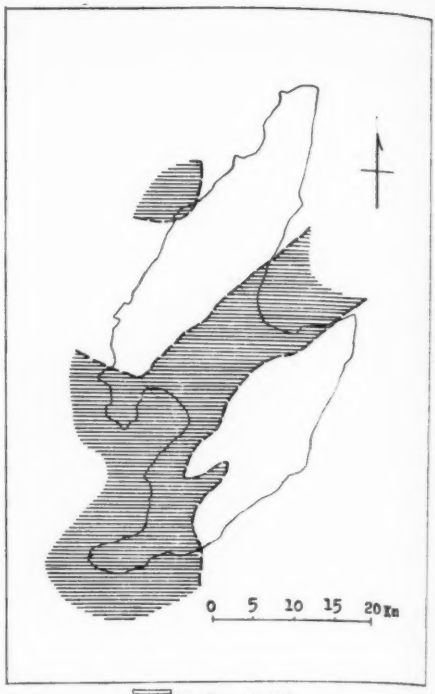
TEXT-FIG. 4—Distribution of Formation O in Island S.



Ost: Ostrea gravitesta Yokoyama
Op: Operculina complanata d'Orbigny
Mg: Miogypsina kotoi Hanzawa

Ost : abundant
Ost : common
(Ost) : rare
M: Mollusca

TEXT-FIG. 5—Fossil distribution in Formation O.



Marine areas

TEXT-FIG. 6—Paleogeographic map of O stage.

CONCLUSIONS

It can be summarized that some fossil animals are good indicators of the salinity and depth in a few middle Miocene deposits. Sedimentary environments and paleogeography of other Japanese middle Miocene deposits may be treated the same as were Formations B and O.

REFERENCE

TSUDA, KARYU, 1953, Geology of Yatsuo area in Toyama Prefecture: Jour. Faculty Sci. Niigata Univ., ser. 2, vol. 1, no. 2, p. 1-35.

JOURNAL OF PALEONTOLOGY, VOL. 30, NO. 4, P. 981–990, JULY 1956

REVIEWS

DEVONIAN OF THE RUSSIAN PLATFORM, COLLECTION OF REPORTS, All Union Pet. Scientific Res., Geol.-Prospecting Inst. (VNIGRI), (Leningrad and Moscow, 1953), p. 1–312.

This collection of reports was brought to my attention by Dr. Henry V. Howe, who recognized the desirability of translating the titles of the included reports. The list may assist paleontologists and stratigraphers in this country to utilize some of the allied research in Russia.

Most of the forms listed or discussed in the collection of papers are known to American workers; however, some genera and species by Russian authors have not previously been noted, and in many instances the references to the original descriptions are unknown. This is particularly true in the papers by Zaspelova (p. 280–284) and Polenova (p. 285–295) which refer to a number of ostracode genera and species previously described in Russian publications not as yet available to American workers. In these two papers and in one by Domrachev (p. 190–210), new species are mentioned and are considered *nomina nuda*. These new forms, and previously established ostracode genera and species, are listed without figures and descriptions.

In the following list of the various reports included in the publication, an attempt is made to note the types of fossils discussed or listed:

Unification diagram of the stratigraphy of Devonian deposits of the Russian Platform and western slopes of the Urals, by B. P. Markovsky, p. 5–15, (Ammonoidea, Brachiopoda, Ostracoda).

Stratigraphic diagram of the lower Paleozoic (Pre-Devonian) deposits of northwestern Russian Platform, by B. S. Sololov, p. 16–38, (Anthozoa, Brachiopoda, Bryozoa, Gastropoda, Graptozoa).

Geological problems of the Devonian of the Russian Platform, by D. V. Nalivkin, p. 39–48, (Ammonoidea, Brachiopoda, Ostracoda).

Stratigraphic diagram of the Pre-Baltic Devonian, by P. P. Lieninsh, p. 49–57, (Brachiopoda, Pisces).

Relationship of the main Devonian field to the Central field and the Southern Trinand, by L. S. Petrov, p. 58–72, (Brachiopoda, Branchiopoda, Ostracoda, Pisces).

The stratigraphy and fauna of the Upper Devonian of the main Devonian field of the Russian Platform and its facies changes, by R. F. Gekker, p. 73–86, (Algae, Brachiopoda, Pisces).

The stratigraphy of the Upper Bright Colored Layer of the main Devonian field, by N. M. Muzechenko, p. 87–93, (Charaphyta, Ostracoda, Pisces).

Devonian regions of the Central Platform, by M. F. Filippova, p. 94–102, (Annelida, Brachiopoda, Branchiopoda).

Pre-Devonian and Devonian deposits of the central part of the Russian Platform, by R. M. Pistrok, p. 103–112, (Annelida, Brachiopoda).

The Devonian of the central Devonian field, by M. M. Tolstikhina, p. 113–120, (Brachiopoda, Branchiopoda).

The stratigraphy of Devonian deposits of the Volga regions, by V. N. Tikhi, pp. 121–131, (Ammonoidea, Annelida, Brachiopoda, Branchiopoda, Ostracoda, Pelecypoda, *Tentaculites*).

Lithologic-stratigraphic characteristic of Devonian deposits in the Saratov's Region, by M. G. Kondratieva & T. E. Fedorova, p. 132–145, (Brachiopoda, Branchiopoda, Foraminifera, Ostracoda).

Devonian deposits in the Kuibyshev region, by S. I. Noboshelova, p. 146–152, (Ammonoidea, Anthozoa, Brachiopoda, Ostracoda, Pelecypoda, *Tentaculites*).

Devonian Tartar, the background of the whole autonomous Soviet Socialist Republic's geological structure, by Y. E. Tehyenckay, p. 153–165, (no fossils discussed).

Stratigraphical diagram of the Devonian deposits in the Tartar Autonomous Soviet Socialist Republic, by V. E. Troypolckee, p. 166–178, (Algae, Ammonoidea, Anthozoa, Brachiopoda, Branchiopoda, Nautiloidea, *Tentaculites*).

Recent deposits in the Bashkir trap, by K. R. Temyrgazen, p. 179–183, (no fossils discussed).

Middle and Upper Devonian deposits in the Bashkir trap, by M. F. Mekrukob, p. 184–189, (Ammonoidea, Brachiopoda).

The Devonian of the western slope of the middle and southern Urals, by S. M. Domrachev, p. 190–210, (Algae, Ammonoidea, Anthozoa, Brachiopoda, Mollusca, Nautiloidea, Ostracoda: *Beyrichiella*, n. sp., Polenova, *Bythocypris* aff. *B. parsonia* Wils., *Carbonita grandis* Polenova, *Evlanella fregis* Polenova, *Haliella* ex. gr. *F. fissurella* Ulrich & Bassler, *Knoxiella inserica* Polenova, *Leperditia* ex. gr. *L. barbotana* F. B. Schmidt, *L. moelleri* F. B. Schmidt, *Microcheilinella kordonica* Polenova).

The stratigraphy of Devonian and pre-Devonian deposits and Molotov's pre-existing rocks and Ydmyti ASSR, by E. N. Larionova & N. I. Petreneva, p. 211–228, (Algae, Ammonoidea, Anthozoa, Brachiopoda, Nautiloidea, Ostracoda, *Tentaculites*).

Dnieper Devonian—Donetz basin, by Z. A. Meshynena, p. 229–236, (Brachiopoda).

Stratigraphical significance of the Devonian brachiopods, by B. P. Markoyckee, p. 237–242, (Brachiopoda).

Significant stratigraphical tables of the Devonian deposits of the Russian platform and

Ural traps, by B. S. Sokoloy, p. 243–247, (Anthozoa, Brachiopoda, Cephalopoda).

Stratigraphically significant pelecypods from Devonian deposits in the Russian platform, by B. V. Nalebken, p. 248–259, (Anthozoa, Brachiopoda, Pelecypoda).

Stratigraphically significant Stromatoporida, by V. N. Rybenen, p. 260–263, (Anthozoa, Stromatoporoidea).

Significant goniatite facies for Devonian stratigraphy, by A. K. Nolebkena, p. 264–273, (Ammonoidea, Nautiloidea?, Pelecypoda).

Foraminifera of Devonian deposits in the Russian platform and Volga-Ural regions, by E. V. Bikoba, p. 274–279, (Brachiopoda, Foraminifera, Ostracoda).

The stratigraphic distribution of ostracodes in deposits of the main Devonian field, by V. S. Zaspelova, p. 280–284, (Brachiopoda, Ostracoda: *Acantonodella lutkevichi* Zaspelova, *A. terciocornuta* Zaspelova, *Acratia burgiana* Egorov, *A. longa* Zaspelova, *A. pskovensis* Egorov, *A. schelonica* Egorov, *A. spinulata* Zaspelova, *A. tschudovoensis* Zaspelova, *A. vastigata* Zaspelova, *Aparchites calcula* Glebowskaia & Zaspelova, *Buregia bispinosa* Zaspelova, *Cavellina lovatica* Zaspelova, *C. tambovensis* Samoilova, C. aff. *C. punctata* Batalina, *Cavellinella batalinae* var. *suhlovensis* Zaspelova, *C. reticulata* Zaspelova, *Ellesmerina incognita* Glebowskaia & Zaspelova, *Evlanella laschenkoi* Egorov, *E. pendula* Zaspelova, *E. sculptilis* Zaspelova, *Healdianella tricornis*, *Indivisia indistincta* Glebowskaia & Zaspelova, *I. latiformis* Zaspelova, *Kloedenellitina sigmaeformis* Batalina, *Knoxiella donensis* Egorov, *K. konensis* Egorov, *Knoxites argutula* Zaspelova, *K. cornutus* Egorov, *Leperditia* aff. *L. geographica* Hecker, *Mennerella schelonica* Glebowskaia & Zaspelova, *M. tuberosa* Glebowskaia & Zaspelova, *Mica? trapezoides* n. sp., *Milanovskya bicornis* Glebowskaia & Zaspelova, *M. ventrocristata* Zaspelova, *Paraparchites* n. sp., *P. copis* Zaspelova, *Pseudonodella plana* Glebowskaia & Zaspelova, *Semilukiella indicens* n. sp., *Subtella? tenuissima* Zaspelova, *Tetracornella schelonica* Zaspelova, *Tulenia? ovata* Zaspelova, *Uchtovia elongata* Glebowskaia & Zaspelova).

Stratigraphic significance of Devonian Ostracoda of the main Devonian field and Volga-Ural regions, by E. N. Polenova, p. 285–295, (Brachiopoda and Ostracoda: *Acratia* ex gr. *A. gassanovae* Egorov, *A. long* Zaspelova, *A. vastigata* Zaspelova, *A. zadonica* Egorov, *Amphissites pulcher* Polenova, *Bairdia binodosa* Polenova, *B. plicatula* Polenova, *B.* ex gr. *B. tikhyi* Polenova, *Buregia* ex gr. *B. zolnensis* Polenova, *Cavellina planula* Scharapora, *Coeloenellina parva* Polenova, *Costatia* ex gr. *C. cavernosa* Polenova, *Donellina grandis* Egorov, *Ellesmerina philippovae* Egorov, *Entomis* ex gr. *E. calcarata* Richter, *E.* ex gr. *E. variostriata* Clarke, *Evlanella subalveolata* Polenova, *Evlanovia tichonovitchi* Egorov, *Famenella inconditis* Polenova, *Gravia* (*Russia*) *unicostata* Polenova, *Halliella* ex gr. *H. fissurella* Ulrich & Bassler, *Indivisia* n. sp., *I.* ex gr. *I. indistincta* Zaspelova, *Kloedenella accepta* Polenova, *Knoxiella? dubia* Polenova, *Knoxites bolchovitinovae* Egorov, *K. cornutus* Egorov, *K. menneri* Egorov, *Leperditia geographica* Hecker, *Limbatula minima* Zaspelova, *Marginia sculpta* Polenova, *Mennerella krestovnikovi* Egorov, *Mica elegans* Polenova, *M.? parva* n. sp., *M.? shigrovskiensis* Polenova, *Plaoskella famensis* Samoilova, *Pseudonodella plana* Zaspelova, *Russia* ex gr. *R. mustafinovi* Polenova, *Sansabella?* n. sp., *Schweyerina normalis* Zaspelova, *S. ovata* Zaspelova, *Semilukiella zaspelovae* Egorov, *Serenida carinata* Polenova, *S. zadonica* Polenova, *Sulcatia* n. sp., *Tulenia optatis* Polenova, *Uchtovia polenovae* Egorov).

The following is a summary of pages 285–286 discussing the status of work on Devonian ostracodes in the U.S.S.R.:

A systematic study of Devonian ostracodes of the Soviet Union has begun only in the last few years. Before this time and at the beginning of our century, in the papers of geologists and paleontologists (F. B. Schmidt, F. N. Chernishov, P. N. Venukova and others), there had been a few descriptions of a particular type of ostracode—mainly the large *Leperditia* forms. This type of ostracode is widely distributed in the Ural Devonian deposits and a few have been described by E. M. Glebowskaia. R. F. Gekker's (Hecker) description of the type of *Leperditia geographica* found in Narrov's layers of the main Devonian field, must also be pointed out. Exceptionally detailed work was done by M. A. Batalina in described ostracodes of the main Devonian field.

Recent research on Devonian ostracodes include the following: descriptions of ostracodes from a few complex, brightly colored and carbonaceous layers of the main Devonian field (V. S. Zaspelova); and the description of ostracodes from the upper Shevetsk field of central Volga region and the central Devonian field (E. N. Polenova). Some very important descriptions of large groups of ostracodes which have great stratigraphic significance in the Devonian layers of the Russian platform include the following: the families Kloedenellidae and Bairdiidae (described by V. G. Egorov), the family Drepanellidae (described by V. S. Zaspelova), and the family Acronotellidae (described by E. N. Polenova).

It was realized that it was necessary to carry on systematic research on individual families to better understand the new and complex forms found in the Devonian section; without this study, their stratigraphic application would have been very difficult. Upon completion of this study, it will be possible to begin research on all of the groups of Ostracoda as to their specific origins.

Devonian fish in the Russian platform in conjunction with discussions of the Middle and Upper Devonian contact, by D. V. Obroochy, p. 296–301, (Pisces).

Spores—pollen complex in the Devonian Russian platform, by S. N. Naoomoba, p. 302–312, (Spores).

JOHN J. KARPECK
Louisiana State University
Baton Rouge

CLASSIFICATION OF CLYPEASTEROID ECHINOIDS, by J. Wyatt Durham. Univ. California Publ. Geol. Sci., vol. 31, no. 4, p. 73–198, frontispiece, pl. 3, 4, 38 text-fig.

This comprehensive review of the systematics and nomenclature of one order of Echinoids is prefaced by sections on external morphology (8 p.), internal morphology (2 p.), growth (6 p.), structure (10 p.) and variation in structure (11 p.). A selected list of 92 references shows not only the complexity of the subject but also the care taken by the author to cover every aspect of it. Special attention is directed to this exemplary feature. A long list of works in which Clypeasteroid species are described, though more imposing superficially, would have borne witness only to the industry of a mere compiler; here we are treated to the discrimination of an intelligent writer. The iconographic literature is in any case adequately dealt with by shorthand references in the synonymies.

The preliminary sections are lavishly illustrated by line-drawings, mostly new, prepared by the author with the firmness and clarity usual in his work. These illustrate the morphological facts underlying the author's new classification, in which the evidence of the relationships between plates is used in addition to the characters formerly relied on. It appears that the number of plates on the oral surface in any species does not change appreciably with growth after metamorphosis, though new plates are added to the petals as long as growth continues. Outside the petals, therefore, growth is almost entirely a result of the addition of matter to existing plates and scarcely at all of the introduction of new plates. Ontogenetic changes in the relationships between plates are traced and importance is attached to the adult condition, especially as regards the basicoronal and first post-basicoronal rows, and the presence of one or two interambulacral plates at the head of each area adjoining the apical system. In the section on growth, much use is made of Deutler's evidence refuting the fallacy that resorption is a universal and important factor in the growth of echinoids. This long overlooked study should be fed to all future echinologists on weaning.

In the new classification, the order Clypeasteroida is divided into four suborders, embracing respectively 2, 3, 10 and 1 families. The suborders Scutellina and Rotulina, attributed to J. E. Gray (1825, 1855) are in fact new taxa in the order-group. In the suborder Clypeasterina there is little change from Mortensen's arrangement beyond the splitting of the Arachnoididae into two subfamilies (Arachnoidinae, s.s., and Ammotrophinae, new) each with one new genus. The many "subgenera" and "sections of *Clypeaster* itself are all suppressed as subjective synonyms of the parent genus—a step regarded as desirable by Mortensen. Mortensen's suborder Laganina, in which he included all remaining Clypeasteroids, is now divided into three suborders, corresponding roughly to (a) Fibulariidae and Laganidae, (b) Scutellidae (excluding Rotulinae) and (c) Rotulinae of his scheme. In the first suborder (Laganina) the family Neolaganidae Durham is added to the two families in (a) above. The second (Scutellina) is the subject of the most intensive revision, for four new families are proposed in it (Protoscutellidae, Eoscutellidae, Abertellidae, Scutasteridae), while three new genera are proposed in the family Echinarachniidae. The third suborder (Rotulina) contains only the family Rotulidae. The genus *Fossulaster* is placed in the suborder Clypeasterina, family uncertain; three genera in Scutellina are in the same situation (*Scutulum, Proescutella, Samlandaster*). The genera *Runa* and *Tournoueraster* are not assigned to any suborder, but the author is perhaps over-conscientious in recognizing them at all. Both are based on internal moulds and are likely to remain *nomina dubia.*

The author has examined material of all the genera dealt with except in the case of many of the "sections" of *Clypeaster*, 8 (out of 27) genera of Laganina and 3 (out of 32) genera of Scutellina. In some of these cases published information is adequate for the author's purpose, but he is always careful to state when his interpretation is based on the literature alone. It is unlikely that any previous author on this group has had such wide first-hand experience, or has examined his material so thoroughly.

Compared with Mortensen's classification, the main changes are in the higher levels. Some of his family-group taxa are still recognizable, although he is shown to have made wrong familial attributions for some genera and to have been too ready to suppress others as synonyms. The classification of Lambert & Thiéry is now shown to have been unreal.

The modesty of the author's style enhances the impression, which grows with reading, of the work's soundness. The new classification grows naturally out of the great quantity of new morphological facts. The only large defects so far noted are two: no attempt is made to compare the new scheme with what has gone before; the phylogenetic conclusions are not segregated in a special section, but are to be found in the chapter on systematics (p. 113–117) rather remote from the frontispiece which illustrates them.

Misprints are few. On p. 86, paragraph 2, "plates 1 and 2" should read "plates 3 and 4"; on p. 172, under *Mellita*, "plate 2" should read "plate 4," and on p. 173, "plate 1" should read "plate 3"; on p. 137, first line of comments on *Lenita*, "scutellinids" should read "fibulariids"; on p. 149, last paragraph, line 3, for "lower" read "middle" and in the last line, for "pre-lower" read "pre-middle." At too late a stage for incorporation in the text (p. 85) the author discovered Kirchner's work (Zool. Jarhb., Abteil. Anat. und Ontog., vol. 51, p. 299–312, 1929) showing that the optic axis of echinoid plates (each of which is a single calcite crystal) is not always normal to the external surface of the plate, but may be oblique to or parallel with this surface, in various directions. The author himself has drawn my attention to these points.

R. V. Melville
Geological Survey and Museum, London
(by permission of the Director)

Stratigraphical Palaeontology, by E. Neaverson. Oxford University Press. 2nd. ed., 806 p., 90 Text-fig., 18. 1955. Price $16.80 (£5.5.0).

The first edition of this book which appeared in 1928, dealt primarily with British fossils. It was widely used, however, outside Great Britain, because many type and other important stratigraphic sections occur in England and Wales. The interval between the two editions is a long one and after 27 years a book of this type could not be simply re-edited. It should be rewritten. The present book is a compromise. In his foreword, the author explains that he has wished to meet two outstanding criticisms which had been leveled against the first edition. One was that a chapter on the morphology of fossils was out of place, consequently this has been omitted from the new edition. The other criticism had been to the effect that only British fossils were discussed, hence the author has now added extensive discussions of non-British faunas. As a result the book has grown from 525 to 806 pages, in spite of the complete omission of 55 pages of morphological descriptions, and the number of text-figures has increased from 70 to 90, although several were deleted with the morphological chapter and 17 were transferred to plates in the back of the new edition.

A change in emphasis is illustrated by the change of subtitle from "A manual for students and field geologists" in the first edition, to "A study of ancient life-provinces" in the second. In other words, it covers the field of paleobiogeography. Surprisingly, the only existing book in which this word occurs in the title (Joleaud's "Atlas de paléobiogéographie," 1939) is not mentioned.

In its general plan and content the second edition follows the first and considerable parts of the first edition have been reprinted. In this way, many parochialisms of the first edition are anachronistically preserved in the second. For example, on p. 3 we find a table of the English stratigraphic succession presented as "Classification of sedimentary rocks." Here, the Tremadoc is retained in the Cambrian, the Carboniferous is divided into "Coal Measures" and "Avonian," there is no Paleocene, and so forth. Similarly, after a brief description of modern marine molluscan provinces (p. 40) the author dismisses the necessity to discuss them in detail, "since many of them have little (if any) connection with British geology." However, the author would no doubt be the first to admit that the study of modern life provinces provides important clues to the interpretation of ancient ones.

The original chapters III to V, "Preservation and occurrence of fossils," "Faunas in relation to habitat," and "Geographical distribution and migration," have been amalgamated into one called "Preservation and distribution of fossils." The text itself is virtually unchanged, except for a brief reference to fossil coral reefs on p. 35, and a few paragraphs on the importance of ocean currents for the distribution of marine invertebrates. This is a highly readable and interesting chapter which might have profited much from the introduction of modern references. C. G. J. Petersen (quoted as "C. G. H. Peterson," p. 28) is still the latest authority

on marine ecology, and Dollo on biologic adaptation. We miss such household words as biotope, neritic, and many other ecological terms. References to Ekman's "Zoogeography of the seas," to Termier's "Histoire géologique de la Biosphère," Hesse's "Ecological animal geography," Kuenen's "Marine geology," to mention only a few modern works, would have improved the general usefulness of this chapter.

By comparison, the following chapter which deals with "Fossils as guides to horizon" has been considerably modernized and it has been further enlarged by transfer of most of the illustrations from the old morphological chapter. At the end of this chapter, among the 18 bibliographic references there are only four papers later than 1940 and none to works in languages other than English. One would perhaps have wished for more emphasis on fossils as means for establishing exact standards for correlation and chronological succession of rocks. In its present form it is a very short and somewhat generalized geologic history of the major animal phyla. Less than a page has been devoted to the plants. Some statements are disturbing, such as that of the occurrence of crinoids in the Cambrian, of *Agoniatites* in the Silurian, and of *Nautilus* in the Jurassic.

The main part of the book (p. 125-701) is devoted to a discussion of the faunas of the successive geological periods. Logically, the chief emphasis is on the invertebrates. Vertebrate faunas are dealt with in two separate chapters, one on Paleozoic, the other on Mesozoic faunas, and one relatively short chapter is devoted to fossil plants. In general, the arrangement of all chapters is similar. For each period the faunas of England and Wales are described first. This discussion is followed by a review of the faunas of the period on a more world-wide basis. On the average about equal space has been allotted to British and non-British faunas. But for periods such as the Permain and the Triassic, which are poorly represented in England, foreign occurrences have received much more space. On the other hand, the classical English Jurassic has received twice as much space as that devoted to the faunas in rest of the world. It would be foolish, however, to look for perfect balance in such a book. The description of British faunas and their succession is essentially reprinted unchanged from the first edition, with the exception of the chapter on the Jurassic which has been modernized and considerably enlarged.

Much valuable and interesting material has been assembled in the chapters on the composition and distribution of non-British faunas. Inasmuch as this constitutes the first attempt to review the succession of life on this scale and with as much detail as is done here, this compilation will prove useful to paleontologists and geologists alike. This has been no easy task and criticism in this field may well appear to have been written inside the proverbial glass house. Nevertheless, the regrettably sparing use of the literature of the last 15 to 20 years should be noted. Thus, the bulk of modern research on the Paleozoic of North Africa (Morocco), of eastern Asia and of Australia (especially Western Australia and Tasmania) has been ignored, and only a minute fraction of the progress of the last 20 years on North American faunas and stratigraphy has been considered. For example, instead of the out-dated correlation tables on p. 180, 226, and 264, modernized tables could have been compiled from the stratigraphic correlation charts prepared by the Committee on Stratigraphy of the National Research Council and published in the Bulletin of the Geological Society of America since 1942. The usefulness of the book would have been further increased by the addition illustrations of non-British fossils. There are no figures of fusulinids and few of other Foraminifera, no figures of corals in the stratigraphic part, and no figures of Permian fossils of any kind. It would also have been helpful to have given the exact horizon and locality for the many illustrated British fossils.

The increase in number of illustrations as compared with the first edition is due largely to the addition of maps showing the distribution of rocks of the systems in different parts of the world. On most maps, this is done by placing large black circles in the general area of the occurrence of the rocks, but this representation gives only a very approximative picture. One would have welcomed more accurately informative, yet simplified, maps like Fig. 71 which shows the distribution of Mesozoic deposits in Western Europe.

The book concludes with a most interesting and stimulating chapter, entitled "General relations of the continents and oceans: a summary of conclusions." Here the paleogeographic history of the continents and the history of their land faunas is briefly reviewed, and this is followed by a discussion

of marine sequences around the present oceans and possible former connections between them. The author rejects both continental drift and the theory of land bridges and maintains that "the evidence of marine faunas throughout the ages is consistent with the older view of stable ocean basins with fluctuating margins, and the continental faunas show such a measure of isolation that the land-masses of the globe must have had approximately their present relations during the whole history of the tetrapod animals." In this judgment, the author is not alone, but references to modern literature are lacking.

In conclusion, this book still stands alone in its field. In the 27 years since the publication of the first edition there has been nothing to replace it, or even to compete with it, in any language. Thus, the new edition will take its place among standard reference works in geologic libraries, and paleontologists and stratigraphers will want to keep it within arm's length for ready reference.

CURT TEICHERT
U. S. Geological Survey
Denver, Colorado

ATLAS OF PALEOGEOGRAPHIC MAPS OF NORTH AMERICA, by Charles Schuchert, with an introduction by C. O. Dunbar: New York, John Wiley and Sons, 177 p., ring binding, 1955.

Charles Schuchert's "Atlas of paleogeographic maps of North America," recently issued, recalls vividly this reviewer's graduate student days at Yale nearly 30 years ago, and the little office and workroom of Professor Schuchert at Peabody Museum. There, on a table by his desk, were a set of 90 or more large outline maps of North America, printed on durable paper, yet worn and dog-eared from constant use, and from many pencilings and erasures. These were the working copies of his series of paleogeographic maps of North America, nearly completed. "Nearly," but not quite, as Schuchert devoted some or much time on them each day, entering new information as it was culled from the literature, or as his many correspondents and visitors brought it to him. Like many other great enterprises, completion was never attained. Stratigraphic and tectonic geology are dynamic subjects; new information, refinements, and interpretations appear constantly. Schuchert continued the work on his maps up to the time of his death in 1942.

The present atlas thus shows the status of working copies when they finally had to be laid aside. Their editors, C. O. Dunbar and Clara M. Le Vene, have rightly refrained from attempting any additions or corrections to bring them up to date. Improvements could have been made, but the essential flavor of the originals and the personal touch of their compiler would have been lost. In the form now published the maps represent an inventory of knowledge of the paleogeography of North America as it stood about 15 years ago.

Many circumstances attending compilation of the maps are set forth in a sympathetic introduction by Dunbar, and much of Schuchert's underlying philosophy has been presented in his publications, notably in his classic "Sites and nature of the North American geosynclines," his presidential address before the Geological Society of America in 1922. These matters need be treated only incidentally in this review, which it seems worth devoting to comments on the underlying plan of the maps, the methods used in compilation, and the principles employed in drawing outlines of the successive seas. Understanding of these matters by users of the maps will greatly enhance their usefulness.

PLAN OF THE MAPS

The present set of paleogeographic maps differs notably from those commonly published, even those which have appeared in successive editions of Schuchert's own textbooks on historical geology. Unlike the others, they do not show gross paleogeography of a large fraction of a geologic period, but paleogeography of rather minute stages that represent, geologically speaking, moments in time. The Paleozoic era is portrayed by 58 maps, the Mesozoic by 18, and the Cenozoic by 8; for the Ordovician alone, there are 12 maps. It was from these working copies, consisting of many maps, that the more generalized ones previously published by Schuchert were compiled.

The plan is commendable, although it rests on the insecure foundations of existing knowledge and techniques; many of the stages chosen are so minute that they lie well within limits of error by available methods of correlation. Thus, some rather abundantly fossiliferous Ordovician formations of the northwestern states have been

variously correlated by different paleontologists with the Trenton, Eden, Maysville, or Richmond of the northeastern states; agreement may be greater today, yet it is doubtful whether any authority would be willing to pinpoint a unit in the northwest as closely as one of the six stages into which this time span is divided on the maps. Another problem is offered by thick geosynclinal units, such as those in Nevada, in which several time-stratigraphic zones may have been recognized but intervening ones not verified; for such Schuchert adopted the operational solution of retaining the seas in the area through the known time span of the unit.

The rather wide limits of error within which he had to operate were doubtless well-known to Schuchert himself, and it was clearly his intention to refine his representations as precision in correlations increased.

METHODS OF COMPILATION

The detailed subdivision of geologic time on the maps would seem to impose similar refinements in assembling, cataloguing, and appraising the source data, yet, to the reviewer's knowledge, Schuchert developed no real system of record keeping, save on the maps themselves, in marginal notes thereon, and by filing items away in his prodigious memory. This was largely sufficient for the unsophisticated days of more than 30 years ago, but would be hopelessly inadequate today for utilizing the great amount of information that is available and accumulating. A somewhat comparable modern enterprise, the Paleotectonic Map Project of the U.S. Geological Survey, employs a staff of many people, and uses an elaborate file of cards, punched for mechanical sorting and screening.

Even during the earlier days, Schuchert's method contained inherent sources of error, for not all items used could be adequately judged, and some items, once entered on inadequate or incorrect information, remained on the maps long after they had been discredited. Thus, on maps 26 and 27, a Middle Silurian sea is extended into northern Chihuahua, Mexico, and a spot of outcrop of that age is there indicated. This is based, the reviewer understands, on a casual observation by a mining geologist of long ago that the great limestone cliffs of the country resembled the Niagaran of his homeland. The cliffs are, of course, the well-known Lower Cretaceous rudistid limestones of the Mexican border country, rocks whose character and age were quite familiar to Schuchert himself, but he never caught and corrected their erroneous assignment to the Silurian.

Entries of data on the maps after 1930 appear to have been spotty. The subsurface Jurassic of the Gulf Coastal Plain, proved since then, is correctly shown on maps 67 to 69. But no record is made of the underlying salt series, the source of the salt domes and certainly one of the major evaporite bodies of the United States, on maps of either the Jurassic or Permian periods, in which the evaporite epoch has been variously placed by different geologists. There is, likewise, no indication of any Middle Ordovician in west Texas, although some hint of its existence was obtained during C. L. Baker's reconnaissance of the Marathon outcrops in 1917, and although the subsurface Middle Ordovician of the Permian basin (Simpson equivalent) was proved at about the same time as the Coastal Plain Jurassic.

PRINCIPLES USED

Compared with some other attempts at paleogeographic representation, the maps seem refreshingly guileless and unimaginative, an objective joining of seaways between equivalent deposits without attempt to force their patterns into preconceived notions of grain or trend. On maps 12 to 16 the Middle Ordovician rocks of the Ouachita Mountains of Oklahoma are placed in the same embayment of the sea as those of the very different rocks of about the same age in the Arbuckle Mountains; no hint is given of the two geosynclinal troughs in which many geologists believe these contrasting sediments accumulated.

This objectivity is at its best in the broad central interior of the continent that was covered by shallow, ephemeral, constantly shifting seas during Paleozoic and Mesozoic time. The odd, amoeboid patterns of these seas on successive maps undoubtedly convey a high degree of accuracy. Even narrow channels hundreds of miles long, carried across country where no data are available, to join distant well-authenticated seas on the east and west or north and south have a genuine basis in faunal affinities as they were known to Schuchert; barriers that appear from time to time across otherwise con-

tinuous seaways similarly express faunal differences.

Yet despite the apparent artlessness of the maps they do contain a strong element of inference, and are a strange mixture of the objective and the subjective, the subjective element increasing greatly from continental interior to continental margin. Along the continental margins representation would admittedly be difficult for any paleogeographer; the older rocks are increasingly more deformed, more metamorphosed, and in part increasingly buried by coastal plain deposits. Here, on Schuchert's maps appear the "borderlands," of which he was the outstanding American advocate and champion, but of whose existence many geologists are now in doubt. In this connection it is instructive to compare Schuchert's maps of Middle Ordovician time, 12, 13, and 14, with Kay's map of early Medial Ordovician time (pl. 1, Geol. Soc. America Mem. 48); the latter indicates narrow, discontinuous "tectonic lands" where Schuchert shows massive "borderlands." The wide disparity indicates, at the very least, the poverty of paleogeographic fact along the continental borders, and demonstrates the strong reliance on inference that all paleogeographers must accept in such areas.

A necessary consequence of the "borderland" theory are the mysterious "portals" through which the seas were admitted through the borderlands from the oceans to the continental interior, the most persistent being in the modern St. Lawrence estuary, the Mississippi embayment, and the Los Angeles area of Southern California. A count of the 58 Paleozoic maps shows that the seas were in the St. Lawrence "portal" during 33 stages, the Mississippi Embayment "portal" during 47 stages, and the Los Angeles "portal" during 42 stages. Considerable justification exists for the St. Lawrence "portal" as this is the region where the Appalachian belt passes beneath the waters of the Atlantic, yet one wonders why, on 18 of the maps, the seas were laid over the southeast edge of the Canadian Shield (for example, on the Middle Devonian map 34) where, at most, only a fragmentary sequence of Cambrian and Ordovician is now preserved. For the Mississippi Embayment "portal" no evidence exists one way or another, as the Paleozoic is buried by several miles of younger coastal plain sediments; modern concepts of the tectonics of this area would seem to make existence of this long-submerged "portal" rather unlikely. Most surprising is the Los Angeles "portal." It is true that the Transverse and northern Peninsular Ranges of that area contain, in their metamorphic complexes, altered rocks of presumed Paleozoic age, but all that is actually known of their age is based on a few poorly preserved lots of fossils, representing two or three later Paleozoic stages. If the maps are to be believed, sediments of all but 16 of the 58 Paleozoic stages should be represented in the complex, which, before metamorphism, should have constituted a rock sequence exceeding in completeness those of the great geosynclinal sections of the Great Basin.

Among minor curiosities of the continental borders, one notes the exceedingly long, narrow land strip which follows the strike of the northeast part of the Appalachian geosyncline during parts of Early and Middle Ordovician time (maps 9 to 13), and the large land masses along the Texas Gulf Coast at two stages of Early Cretaceous time (maps 70 and 72). The first is in an area where the stratigraphy is well known, and the land strip is evidently a holdover of the now discredited "trough and barrier" theroy of Ulrich. The second, although in an area where the rocks in question are deeply buried, will probably startle Coastal Plain geologists. These Early Cretaceous land masses, as the reviewer recalls, are the last shred of a theory strongly urged at one time by Schuchert, of a reactivation of his "borderland" of Llanoria during a long span of Cretaceous time. In the face of overwhelming contrary evidence the reactivated "borderland" had to be removed from most of the Cretaceous maps, but evidently Schuchert could never bring himself to relinquish the idea completely.

CONCLUSIONS

These remarks indicate, I think, that paleogeography is more art than science. Like art, what is regarded as paleogeographic perfection by one generation appears merely quaint and curious to the next; no doubt generations that follow will look with equal curiosity on our own concepts. Be this as it may, Schuchert's massive achievement will never be excelled by any other geologist working alone and will probably be difficult to match by any team of geologists.

From a lifetime of single minded and monumental endeavor, Schuchert's pioneer work in paleogeography will stand as a guide to all future studies in paleogeography and paleotectonics. As an aid to such work, it is indeed fortunate that the editors and publisher have seen fit to issue the original working set, rather than allow Schuchert's record to stand on the more generalized maps that have hitherto been available.

PHILIP B. KING
University of California and
U. S. Geological Survey, Los Angeles

GEOLOGY OF JACKSON COUNTY, FLORIDA, by Wayne E. Moore, Florida Geological Survey Bulletin 37 (Tallahassee, 1955), 101 p., 17 text-fig., 5 pl., including geologic map of county on scale 1″ = approx. 2.17 mi. Paper cover.

Jackson County is strategically located in the transition belt between the Gulf Coastal clastic sediments and the more carbonate sediments of the Florida Peninsula and West Indian Region. The type locality of the very distinctive lower Oligocene Marianna limestone is located in Jackson County. This limestone is traced westward to Vicksburg, Mississippi, but cannot be recognized a short distance east of its type locality because of facies change. Many excellent and abundantly fossiliferous exposures of the upper Eocene Ocala (Crystal River) limestone occur in Jackson County.

Inasmuch as these are classic localities of well-known mappable units which required additional detailed investigation, it was fortunate that Jackson County was selected for study by the Florida Geological Survey. It was also fortunate that Dr. Moore, a micropaleontologist with knowledge of West Indian Foraminifera, accepted the task of mapping this area. He could consult freely with Dr. W. Storrs Cole, an authority on the geologic and geographic ranges of the larger Foraminifera (orbitoids and camerinids). This bulletin contains a wealth of information on the geomorphology of the county and the stratigraphy and paleontology of the upper Eocene and younger beds. The Florida Geological Survey is to be commended for publishing this report, although the Survey staff does not agree with Moore in his structural interpretations and subdivisions of the upper Eocene (Ocala) limestone (stated in the letter of transmittal).

Moore, from his study of cuttings samples from several core-holes near Cypress, east-central Jackson County, recognized the Cypress fault—a normal fault striking northeast-southwest, dipping steeply to the southeast, and with a maximum stratigraphic displacement of about 100 feet. The age of the fault, or its last movement, is early Miocene. Proof of such a fault is inadequate although the upper Eocene is thinner and of a more shallow water phase northwest of Cypress than in the contemporaneous beds to the southeast. It appears more likely that this area lies within the northwestern part of the Suwannee Strait, a Tertiary channel comparable to the present Florida Strait, which extended eastward from Jackson County along the Georgia-Florida boundary during the early Tertiary. Ocean currents passing through this channel swept out the sediments during periods in early Tertiary time, but the currents subsided during the upper Ecoene and Oligocene and the trough was filled with thicker and deeper water sediments than equivalents to the north and south. The strait acted as a barrier to the migration of shallow water benthonic faunas between the eastern Gulf Coast region and the Florida Plateau, especially during the Oligocene epoch. The Suwannee limestone (Oligocene) of peninsular Florida has very few species in common with the equivalent Oligocene sediments of Alabama and western Florida. The prominent facies change of the Marianna formation, from its typical character west of Jackson County, occurs at the edge of the Suwannee Strait, only a few miles east of the type locality. The data, therefore, appear to support paleogeographic and environmental changes rather than faulting.

Moore, following Puri, uses Ocala group for the upper Eocene sediments in Jackson County, but recognized only one formation (Crystal River) of the Ocala at the outcrop. He introduces a new member (Bumpnose) of this formation, though it can be recognized only at the outcrop across the western half of the county. For deeper water facies of the Crystal River formation, known only in the subsurface of eastern Jackson County, and other counties farther east and south, he assigns a new formational name, Gadsen limestone. Moore does not recognize the Moodys Branch formation and late middle Eocene sediments in Jackson County; he believes that the absence of this part of the

section was caused by post-middle-pre-upper Eocene uplift and erosion.

The beds comprising the Bumpnose member of the Crystal River formation have been placed in the Oligocene and correlated with the Red Bluff formation by MacNeil. The reviewer, also, believes that there is more evidence, both lithologic and paleontologic, for an Oligocene age for these beds, and that they should be called Red Bluff; no new name is needed.

It is natural that a paleontologist should note the change in the facies of a formation, from shallow marine to deep marine, and that he use stratigraphic names to differentiate the two. However, stratigraphic nomenclature will become too unwieldy if formational names are applied to each change of facies. The Ocala limestone has been variously subdivided in peninsular Florida; its equivalent, the Jackson group, has several subdivisions in Mississippi and Alabama, based mainly on lithology. Deeper marine facies of this section are known to be present in the subsurface of the middle and western Gulf Coast area, but no new names have been proposed for these facies. The new formational name, Gadsen limestone, proposed by Moore for a deeper water facies (deposited in the Suwannee Strait) of the Ocala limestone hardly seems justified.

Moore believes that the Moodys Branch formation (basal formation of the Jackson group) is absent from Jackson County, though its equivalent is recognized in peninsular Florida. An uplift at the end of middle Eocene is postulated to account for the absence of the Moodys Branch and the late middle Eocene beds. Most paleontologists who have studied well samples from Jackson County recognize Moodys Branch in the wells, on the basis of lithology (glauconitic marl) and large Foraminifera—Moore believes that the supposedly Moodys Branch orbitoidal and camerinid Foraminifera are actually middle Eocene forms. The reviewer believes that deposition was interrupted only slightly in Jackson County at the end of middle Eocene time; that the Moodys Branch formation is present, but thin; and that late middle Eocene is represented by a section thinner than that in the Suwannee Strait area or that in the western Gulf Coast. Experienced commercial paleontologists are well aware that most well cuttings are not reliable for differentiating thin stratigraphic units; these samples are contaminated and frequently mislabeled. Evidently these facts were not taken into account by Moore.

Twelve pages of the report are devoted to the geomorphology of Jackson County. Three geomorphic units are recognized: (1) Delta Plain Highlands, (2) Terraced Coastal Lowlands, and (3) River Valley Lowlands. The Delta Plain Highlands include the highest elevations in the county (up to 320 feet) and occupy a small area in the southwestern part of the county. The Highlands are underlain by the "Citronelle" formation, probably Pleistocene in age. Most of the county is covered by a veneer of Pleistocene terrace deposits which lie on the upper Eocene, Oligocene, and lower Miocene formations. It appears likely that the very large ancestral Chattahoochee River followed various courses across Jackson County. The river entrenched wide valleys in the Tertiary formations during lower Pleistocene base levels. Sediments underlying the river terraces and coastal plain lowlands were deposited during rising and high sea level stages. The reviewer agrees with Moore that solution of the Tertiary limestones has been unimportant in developing the lowlands.

A detailed account of the courses followed by the Pleistocene rivers, together with a description of the alluviation of the river valleys, would add much to our understanding of Pleistocene history in the eastern Gulf Coast. The large areas of "Residuum" north and northeast of Jackson County, shown on MacNeil's maps of the Tertiary formations of Alabama and of Georgia, are probably of the same origin as the Pleistocene terrace deposits of Jackson County. Moore emphasized the geomorphology of the depositional surfaces rather than the underlying sequences of sediments.

This report on Jackson County is a real contribution to the geology of the eastern Gulf Coast, notwithstanding the reviewer's criticism of some of Moore's conclusions. The detailed descriptions of numerous exposures of upper Eocene and Oligocene formations, together with lists of Foraminifera which occur in the beds exposed, make this bulletin valuable to all geologists who work in the eastern Gulf Coast.

E. H. RAINWATER
Shell Oil Company
Houston

JOURNAL OF PALEONTOLOGY, VOL. 30, NO. 4, p. 991–1028, JULY 1956

SOCIETY RECORDS AND ACTIVITIES

REPORTS AND MINUTES OF THE THIRTIETH ANNUAL MEETING OF THE SOCIETY OF ECONOMIC PALEONTOLOGISTS AND MINERALOGISTS

The thirtieth annual meeting of the Society of Economic Paleontologists and Mineralogists was held in the Waldorf Room of the Conrad Hilton Hotel, Chicago, Illinois, April 23–26, 1956, in conjunction with the annual meeting of the American Association of Petroleum Geologists.

The Presidential Address of the Society "In Defense of Outdoor Geology," was given by Francis J. Pettijohn at the joint session on Tuesday, April 24.

Also at the joint session, an "Honorary Membership Scroll" was presented to Raymond C. Moore, who was elected to Honorary Membership by the Council in December, 1955.

Born at Roslyn, Washington, February 20, 1892, Moore received a B.A. degree from Denison University, Granville, Ohio, in 1913, with major training in the classics and geology; in 1916 he was awarded a Ph.D. (summa cum laude) from the University of Chicago, in geology, with major work in stratigraphy and paleontology. Denison University bestowed an honorary Doctor of Science degree upon him in 1935.

Dr. Moore was State Geologist of Kansas from 1916 until 1954. His teaching experience includes: instructor of geology at Denison University, 1912–13; assistant professor of geology, University of Kansas, 1916–18; associate professor, 1918–19; and professor since 1919. He was chairman of the Department of Geology at Kansas University from 1920 to 1939 and again from 1952 to 1954.

In November and December of 1947, Dr. Moore was a Distinguished Lecturer for The American Association of Petroleum Geologists. His research and writing are chiefly in the fields of stratigraphy, invertebrate paleontology, geomorphology, and regional tectonics. He is the author of several textbooks on Historical Geology and has published approximately 200 articles in scientific journals.

Moore has been editor of the A.A.P.G. *Bulletin* and the S.E.P.M.'s *Journal of Paleontology* and *Journal of Sedimentary Petrology*. Since 1948 he has organized and directed the Treatise on Invertebrate Paleontology. When completed this will include 22 volumes, 5 of which have already been published and 2 are in press.

Among numerous others both U. S. and foreign, Dr. Moore's scientific affiliations include membership in The American Association of Petroleum Geologists (a Founder) and the Society of Economic Paleontologists and Mineralogists (charter member and president in 1928); fellow of the Geological Society of America; member of the Paleontological Society (president in 1927); member of the American Association for the Advancement of Science; and member of the Kansas Geological Society.

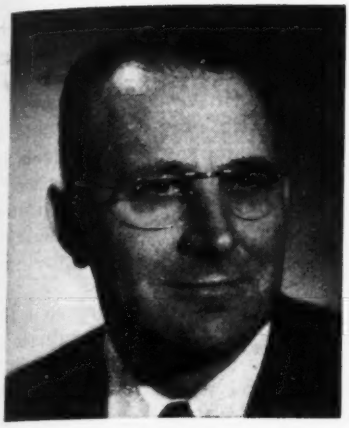
In addition to the Honorary Membership Award, Research Committee Chairman, Raymond Siever, presented the Society's Award for the Best Paper for 1954 in the *Journal of Paleontology* to Donald Parkinson, for his paper entitled, "Quantitative Studies of Brachiopods from the Lower Carboniferous Reef Limestones of England," which appeared in the May issue, Volume 28, Number 3. Mr. Siever also presented the award for the best paper for 1954 in the *Journal of Sedimentary Petrology* to Harold N. Fisk, Charles R. Kolb, Edward McFarlan, Jr., and Louis J. Wilbert, Jr. (deceased), for their paper entitled, "Sedimentary Framework of the Modern Mississippi Delta," which appeared in the June issue, Volume 24, Number 2.

The Best Paper Awards are the second to be presented by the S.E.P.M. They consist of a certificate given to the author, or coauthors, whose paper, appearing in the Journals during the second preceding year, is judged by the Research Committee to be the most outstanding contribution of the year.

Donald Parkinson is a native of Clitheroe, Lancashire, England. He entered Birmingham University in 1919 where he graduated with first-class honors in geology. He obtained the Ph.D. degree from Birmingham in 1925 and the D.Sc. degree in 1936. After

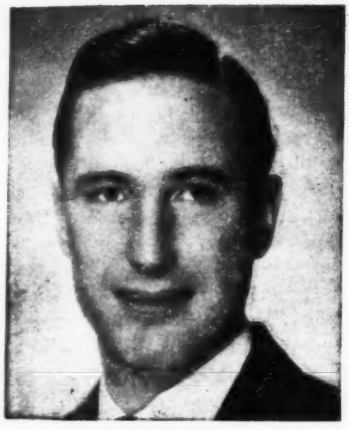
RAYMOND C. MOORE (right) receiving honorary membership certificate from S.E.P.M. President Pettijohn.

DONALD PARKINSON
BEST PAPER AWARD, 1954
Journal of Paleontology



HAROLD N. FISK

CHARLES R. KOLB



EDWARD MCFARLAN, JR.

LOUIS J. WILBERT, JR.

BEST PAPER AWARD, 1954
Journal of Sedimentary Petrology

serving on the geological staff at Queen's University, Belfast, Ireland, from 1925 to 1927, he joined the Dunlop Rubber Company. In 1937 he was awarded the Wollaston Fund by the Geological Society in recognition of his research. In 1953 he was awarded the highest award of the Institution of the Rubber Industry, the Colwyn Medal, for conspicuous scientific and technical services to the Industry. Retiring from the Dunlop Rubber Company in August, 1955, he is now a consultant with the United Carbon Company of Charleston, West Virginia. Dr. Parkinson is an honorary associate of the Birmingham College of Technology, a fellow of the Institute of Physics, and a member of the American Chemical Society.

Harold N. Fisk was born in Medford, Oregon. He obtained his B.A. and M.A. degrees from the University of Oregon in 1930 and 1931 respectively. In 1933 he was granted a Ph.D. in petrography from the University of Cincinnati. His early experience includes research and teaching at the University of Oregon, University of Cincinnati, Northwestern University, and Louisiana State University. In 1935 Fisk joined the faculty of L.S.U., a position he held until 1948 when he became chief geologist, research section, for the Humble Oil and Refining Company in Houston. Dr. Fisk has been a consultant for the Mississippi River Commission since 1941 and was a research geologist for Louisiana Geological Survey from 1935 to 1940. He is a fellow of the Geological Society of America, a member of the American Association of Petroleum Geologists, the Society of Economic Paleontologists and Mineralogists (president, 1953–1954), American Geophysics Union, and the American Society of Civil Engineers.

Charles R. Kolb is a native of Vicksburg, Mississippi. Except for short courses at George Washington and Purdue Universities, his geologic education was received during the years 1937–39 and 1947–49 at Louisiana State University (B.S. in geology in 1948 and M.S. in 1949). He spent one year, 1949–50, with the Snare Engineering Corporation, a consulting engineering firm, on ground-water and dam construction problems in Chile. Except for this period Kolb has worked almost continuously, since 1946, on a part- or full-time basis with the Geology Branch, Waterways Experiment Station, a research laboratory of the Corps of Engineers located at Vicksburg. At present his official title is Chief, Geology Branch, Soils Division. Professional associations include: Fellow of the Geological Society of America, associate member of the American Association of Petroleum Geologists, member of Sigma Xi and the Vicksburg Engineers' Club. Sedimentary processes in alluvial and deltaic environments and their application to engineering problems is his principal field of endeavor. However, his work also involves evaluation of terrain features for military purposes, airfield site selection, and aerial photo interpretation of soils for engineering purposes.

Edward McFarlan, Jr. was born in Brooklyn, New York. His undergraduate work was completed at Williams College in 1943. In 1948, he received a Master of Arts degree from the University of Texas, where he held the Shell Oil Company fellowship during the year 1947. In 1948 he accepted a position with the Humble Oil and Refining Company, Houston, Texas, and is currently conducting research in Quaternary geology. McFarlan is co-author of a paper, "Late Quaternary Deltaic Deposits of the Mississippi River," in the Crust of the Earth, G. S. A. Special Paper 62, 1955. Membership in scientific societies includes the Society of Economic Paleontologists and Mineralogists, The American Association of Petroleum Geologists, and the Geological Society of America.

Louis Joseph Wilbert, Jr., consulting geologist, died March 17, 1953, as the result of injuries sustained in an automobile accident near Opelousas, Louisiana. He was born in Plaquemines, Louisiana, October 21, 1919. He attended Spring Hill College in Mobile, Alabama, for one year, transferring to Louisiana State University in the fall of 1937 to work toward a B.S. in geology. Requirements for the Bachelor of Science were completed in June, 1940, and a Master of Science degree was conferred on him in June, 1942. After his release from the army in 1946, Wilbert began study toward a doctorate at the University of Kansas. The degree of Doctor of Philosophy was conferred on him in June, 1951. Wilbert served as a teaching assistant at Kansas University

and an instructor at L.S.U., later being promoted to assistant professor on the Louisiana State University faculty, and retained that rank until his resignation in 1952 in order to devote most of his time to consulting work. He was appointed a co-editor of the *Journal of Paleontology* for the year 1952. Among other organizations, Wilbert was a member of the Geological and Mining Society of American Universities, American Association of Petroleum Geologists, Society of Economic Paleontologists and Mineralogists, Geological Society of America, and American Geophysical Union.

SOCIETY OF ECONOMIC PALEONTOLOGISTS AND MINERALOGISTS

30th ANNUAL MEETING

PRESENT OFFICERS

President: FRANCIS J. PETTIJOHN, The Johns Hopkins University, Baltimore, Maryland
1st Past-President: HANS E. THALMANN, Stanford, California
2nd Past-President: HAROLD N. FISK, Humble Oil & Refining Company, Houston, Texas
Vice-President: ROBERT R. SHROCK, Massachusetts Institute of Technology, Cambridge, Mass.
Secretary-Treasurer: SAMUEL P. ELLISON, JR., University of Texas, Austin, Texas

EDITORS

A. K. MILLER AND WILLIAM M. FURNISH, *Journal of Paleontology*, University of Iowa, Iowa City, Iowa
JACK L. HOUGH, *Journal of Sedimentary Petrology*, University of Illinois, Urbana, Illinois

OFFICERS-ELECT

President: ROBERT R. SHROCK, Massachusetts Institute of Technology, Cambridge, Mass.
Past-President: FRANCIS J. PETTIJOHN, The Johns Hopkins University, Baltimore, Maryland
Vice-President: RICHARD V. HOLLINGSWORTH, Paleontological Laboratory, Midland, Texas
Secretary-Treasurer: SAMUEL P. ELLISON, JR., University of Texas, Austin, Texas
Editor: WILLIAM M. FURNISH, *Journal of Paleontology*, University of Iowa, Iowa City, Iowa
Editor: JACK L. HOUGH, *Journal of Sedimentary Petrology*, University of Illinois, Urbana, Illinois

HEADQUARTERS STAFF

Business-Manager: ROBERT H. DOTT
Headquarters Secretary: RUTH TENER

CONVENTION COMMITTEES

General Chairman: EDWARD C. DAPPLES, Northwestern University, Evanston, Illinois
Chairman, Technical Program: ROBERT R. SHROCK, Massachusetts Institute of Technology, Cambridge, Mass.
Chairman, Research Committee Symposium: RAYMOND SIEVER, Illinois Geological Survey, Urbana, Ill.

PROGRAM AND ABSTRACTS

Monday, April 23, 1:45 P.M.

Grand Ballroom, Hilton Hotel

RESEARCH COMMITTEE SYMPOSIUM

"DIRECTIONAL PROPERTIES OF SEDIMENTARY ROCKS"

Presiding: RAYMOND SIEVER, University of Illinois, Urbana, Illinois, AND CURT TEICHERT, U. S. Geological Survey, Denver, Colorado

1. INTRODUCTION

RAYMOND SIEVER
Illinois State Geological Survey, Urbana, Illinois

2. FLUME EXPERIMENTS ON THE PRODUCTION OF STRATIFICATION AND CROSS-STRATIFICATION

EDWIN D. McKEE
U. S. Geological Survey, Washington, D. C.

Experiments are being conducted in flumes designed to simulate conditions of deposition (1) through stream current action, (2) by slumping into a standing body of water, and (3) under the influence of wave action. Previous experiments, made in a wind tunnel with dry sand, formed deposits (1) by wind currents and (2) by avalanching down steep slopes. Deposition, stratification, or cross-stratification was developed under each of the five environments. The type of deposit formed depends upon such factors as speed of current, depth of water, size of grain, degree of sorting.

Significant observations from the experiments include: (1) Foreset beds develop without bottomset beds where sorting is good and clay minerals are absent or sparse. (2) Topset beds commonly are eliminated in delta-front deposits through lowering of the water level. (3) Wind-deposited sand on the lee sides of dunes forms strata with dips that consistently are several degrees greater than those of foreset slopes in water-deposited sand of corresponding grain size and texture. (4) Channel profiles tend to be U-shaped where formed by streams flowing down the channel bottoms, semicircular where formed by currents in a standing body of water that fills the channels. (5) Cross-stratification that appears to be upside down, consisting of festoons that are convex upward, can be formed by coalescing lobes at the front of an advancing delta; strata in channelfills, including "festoon" types, vary from those that curve in conformity with the channel to those that are nearly flat-lying as a result of differences in position of water level at or above the channel rims during deposition.

3. SAND-GRAIN ORIENTATION AND GEOLOGICAL APPLICATION

GENE A. RUSNAK
Scripps Institution of Oceanography, La Jolla, California

Theoretical considerations based on the laws of fluid mechanics indicate that the most stable position which an ellipsoidal particle acquires in depositional transport is one in which the long axis lies parallel to the direction of fluid motion, and with a slight dip into the current. Results of an experiment reveal that although large perturbations exist in the process of sedimentation, the theory is valid in a statistical sense. Throughout the study, statistical tests are used for determining the preferred direction of orientation and the degree of orientation.

The reliability of sand-grain orientation, as a means of determining transport direction, is tested in a geological situation containing rigid directional control. The control used in this test is the cross-bedding dip directions of the Mansfield sandstone of western Indiana. A hierarchical sampling design was used in collecting field samples for testing the variability of grain orientation at several levels of sampling. The variance components of grain-orientation direction were then compared with the variance components of cross-bedding dip direction. These results demonstrate the degree of reliability which may be expected in using grain orientation direction as an indicator of sediment transport direction. Conclusions of the study indicate the usefulness of grain orientation as a geological tool.

4. GRAIN ORIENTATION STUDIES OF RECENT SANDS

JOSEPH R. CURRAY
Scripps Institution of Oceanography, La Jolla, California

Grain orientation measurements have been made on oriented thin sections of artificially lithified sands collected from a variety of modern environments. The results of the study have established the existence of a preferred orientation direction of the long axes of the sand grains parallel to the direction of the depositing current. Each environment has shown a characteristic orientation pattern. Statistical methods have been used to express and evaluate the results of all measuremnts.

Sands from a beach foreshore and the wave-washed part of the berm show a preferred orientation direction parallel to the backwash direction of the waves. This direction is approximately perpendicular to the shoreline, although strong longshore currents may cause some deviation. Samples from dunes and the dry part of a beach may be individually well oriented, but show large sample-to-sample variation because of fluctuation in wind direction. Other beach subenvironments have also been investigated.

The preferred orientation direction of a composite of samples collected at random from the narrow abandoned beach ridges, or cheniers, of southwestern Louisiana is approximately perpendicular to the trend of the sand body. The wind-deposited samples tend to mask this preferred orientation, but the consistent good orientation of the wave-washed samples is generally strong enough to produce a statistically significant composite preferred orientation. In contrast, sands from river-sand bars and channel fills show a preferred orientation parallel to the trend of the sand body.

The following applications of sand-grain orientation are suggested:

1. To predict the trend of an elongate sand body, knowing its origin.
2. To determine the origin of an elongate sand body, knowing its trend.
3. To detect the presence and direction of a current depositing or reworking a sand.

5. DIRECTIONAL PROPERTIES OF SOME CALIFORNIA SANDSTONES

L. C. BONHAM
California Research Corp., La Habra, California

Fabric studies of a number of Upper Miocene and Pliocene sandstones of Southern California revealed several directional properties of the sediments and provided logical explanations of their origin. Preferred dimensional orientations that occur in both deformed and undeformed rocks cannot be attributed to rolling or stretching after deposition; therefore, they must be the result of depositional processes. Similarly, crystallographic orientation of quartz in the same rocks is also related to depositional processes by a consideration of the relationships between quartz-grain elongation and crystallographic axes.

Another directional property is velocity anisotropy which, in the samples studied, is correlated with preferred orientation of microfractures.

6. ORIENTED PHENOMENA PRODUCED BY SEDIMENTATION FROM TURBIDITY CURRENTS AND IN SUBAQUEOUS SLOPE DEPOSITS

JOHN E. SANDERS
Yale University, New Haven, Conn.

Turbidity currents may produce structures and fabrics having preferred orientation: (1) by reaction with the bottom prior to deposition of their load, (2) in the process of deposition, or (3) by tractional reworking of the material they deposit.

Flow marks (Generally preserved as flow casts [or flute casts]) and drag marks (generally preseved as groove casts) are formed prior to deposition by the moving turbidity current and record the azimuth and, in certain instances, the direction of the current. These marks closely parallel downslope direction and require a firm substratum for their formation and preservation A turbidity current may pull up a watery clay substratum into attenuated ripple-like forms which in transverse profile are bent over downcurrent.

As deposition takes place, graded bedding may occur and elongate objects (pebbles, shells, plant fragments) tend to be oriented with long axes parallel to current direction, either by being transported in this position or by rotation after striking bottom on one end. Imbrication of platy pebbles may result; both upcurrent and downcurrent dips have been reported. Material is sorted laterally with coarser pebbles generally remaining near the source in any given bed.

After deposition begins, fabrics previously formed may be realigned by tractional shifting which can cause several kinds of current ripples and ripple cross-lamination. On ripple crests elongate particles tend to be oriented with long axes parallel to current direction; in troughs long axes are perpendicular to current direction. Migration of ripples produces ripple cross-lamination.

Internal orientation of fine-grained particles, however formed, may be expressed as parallel partings on bedding surfaces. These partings are parallel to long axes of oriented grains and may be parallel to turbidity current direction (if the grains were oriented by direct deposition from the current) or perpendicular to current direction (if governed by ripple lamination).

Intricate internal folds within a single bed (convolute lamination, whose origin is as yet unknown) may be oriented with axial planes dipping upcurrent.

Deposits on subaqueous slopes may form structures by mass movement due to sliding or load casting. Sliding may give rise to folds and overthrusts (whose orientation can be used to infer slope direction under favorable circumstances), pull-aparts (sedimentary "boudinage"), or slide marks (sedimentary "slickensides" at contact of sliding mass and substratum, which are oriented downslope). Sedimentary loading over a hydroplastic substratum may induce loadcast phenomena which may or may not have preferred orientation. Elongated load-cast structures formed in turbidity-current deposits tend to parallel current direction.

The geopetal value of these phenomena is not considered.

Most of the features described require outcrop examination to infer current direction, Many of these are not limited to deposits laid down by turbidity currents and resemble phenomena formed in other environments of sedimentation (notably glacial) or by tectonic movements. As turbidity current deposits commonly occur in deformed tracts, extreme care is required to distinguish between structures of sedimentary and tectonic origin, and in reconstructing direction of current movement.

7. TRACING TURBIDITY CURRENT DEPOSITS DOWN THE SLOPE OF AN ALPINE BASIN

ALBERT CAROZZI
University of Illinois, Urbana, Illinois

Black pelagic limestones were deposited in the sedimentation basin of the Nappe de Morcles (High Calcareous Alps) during the Upper Jurassic. This deep-water sequence which generally reaches 100–150 meters in thickness, was interrurted at least nine times by coarse-grained clastic beds laid down by turbidity currents. The main constituents of these clastic beds are broken or intact reef-organisms, oolites, and clastic minerals, displaying well characterized graded-bedding. This foreign material originates in the northern margin of the basin along which fringing reefs were growing. As these clastic beds are traced out to sea, as indicated by the regional paleogeography, they disappear one by one; moreover, peculiar topographic conditions allow the study of the textural modifications of a given bed at least 40 kilometers down the basin slope, along the inferred main direction of flow of the turbidity currents. Particularly interesting is the behavior of the apparent maximum diameter of a

given clastic component (index of clasticity) measured at the bottom of the bed, as it may reveal the horizontal grading along the direction of flow. Two main types of variation have been recognized:

1. *Normal types*, corresponding to beds laid down by individual turbidity currents.
   a. The clasticity starts with high values and decreases down the slope following a regular curve toward the end of the bed.
   b. The clasticity decreases along a straight line.
   c. The clasticity remains constant along the entire length of the bed.
2. *Composite types*, corresponding to beds laid down by the interference action of two or more turbidity currents. The clasticity curve corresponds to the juxtaposition of any one of the normal types. Interference of two turbidity currents was commonly observed, the second flow starting deposition when the first was near its end. The clasticity curve displays a first gradual decrease succeeded by a rapid increase (due to mixing) leading to a second and similar diminution down the slope.

These variations of clasticity along the inferred direction of flow of turbidity currents are in general agreement with the experimental data as well as with the mechanics admitted for this peculiar type of sedimentation. However, further studies are required to ascertain their possible use in correlation.

PRESIDENTIAL ADDRESS

Tuesday, April 24, 8:45 A.M.

Grand Ballroom, Hilton Hotel

JOINT SESSION

IN DEFENSE OF OUTDOOR GEOLOGY

FRANCIS J. PETTIJOHN

(For complete address, please refer to A.A.P.G. *Bulletin*, Vol. 40, No. 7.)

Tuesday, April 24, 1:45 P.M.

Waldorf Ballroom, Hilton Hotel

GENERAL PALEONTOLOGY AND STRATIGRAPHY

Presiding: CHARLES COLLINSON, Illinois State Geological Survey, Urbana, Illinois, AND STUART A. LEVINSON, Humble Oil & Refining Company, Houston, Texas

1. ECOLOGICAL INTERPRETATIONS OF THE PLIOCENE AND PLEISTOCENE STRATIGRAPHY IN THE GREAT GREAT PLAINS REGION

JOHN C. FRYE* AND A. BYRON LEONARD
Illinois State Geological Survey, Urbana, Illinois; and University of Kansas, Lawrence, Kansas

In the Great Plains Region a record of changing physical environment, exemplified by fossiliferous sediments, is well preserved. Although broken by unconformities, the record is exceptionally complete from late Miocene or early Pliocene time to the present. Interpretations are based on studies extending from west-central Texas to western Nebraska. Stratigraphic classification and correlations are included as a basis for discussion of changing environmental conditions. Of prime utility in reconstruction of past ecologies are the almost complete succession of fossil molluscan faunas, the abundant plant remains of the Pliocene, the well preserved and extensive Pleistocene buried soils, and the striking development of secondary calcium carbonate as well as the character and distribution of the clastic sediments.

In earliest Pliocene there existed a subdued erosional topography, moderately well watered and vegetated. Alluviation, initiated along major valleys, spread laterally, overlapping gentle erosional slopes, and gradually reduced the local relief. Through the Pliocene there was a slow but progressive drying of the Plains, with gradual elimination of branchiate snails, modification of the typically prairie flora, decline of regional water table and extensive development of caliche. During late Pliocene the marked fineing of sediments suggests a decrease in volume of water

* Person presenting paper.

flowing through the region. Finally, alluviation ceased and an alluvial plain of little local relief, with a climate perhaps as dry as the present, persisted at essential equilibrium for a significant period. With the climatic reversal in earliest Pleistocene, branchiate snails again appeared, and major streams incised valleys—partly alluviated in Nebraskan time. By Kansan time the Plains, after a period of major incision, were again a mesophytic prairie well populated with branchiate snails. The subsequent history of the Plains is characterized by fluctuating but progressive desiccation, evidenced by the complete disappearance of branchiate snails; prevalence of Chernozem, Chestnut, Reddish Chestnut, and Brown soils in interglacial positions; striking increase of loess deposits; and progressive increase in topographic relief. In the Bradyan interval conditions of semi-aridity, similar to those existing today, mark the final phase in progressive desiccation.

2. PROBLEM OF SCIENTIFIC NOMENCLATURE APPLICABLE TO FRAGMENTARY FOSSILS

RAYMOND C. MOORE AND P. C. SYLVESTER-BRADLEY*

University of Kansas, Lawrence, Kansas; University of Sheffield, Sheffield, England

Among fossil remains of animals are multitudinous dissociated fragments which cannot reliably be identified as parts of any known species or genus of whole animals. These include isolated skeletal elements of coccoliths, sponges, octocorals, holothurians, crinoids, cystoids, echinoids, asterozoans, annelids (scolecodonts), the minute toothlike bodies of unknown zoological affinities called conodonts, and such objects as opercula of gastropods, aptychi of ammonoids, fish scales and fin spines, and otoliths. A majority of these fragmentary fossils can be classified readily on form characters and are found to have much importance in stratigraphic paleontology. A retarding influence in describing and illustrating fossil fragments, however, is the great difficulty which has been encountered in devising a suitable system of nomenclature for them. Confusion arises from naming fragments in the manner of whole-animal taxa or treatment of them as "form-genera" and "form-species" subject to zoological rules, and only chaos can result from acceptance of the Paris (1948) decision that names for such fragments are "technical terms" belonging outside the scope of zoological nomenclature. Solution of the problem is offered in proposing for fragmental remains of animals a distinct category of classificatory units termed parataxa (associate taxa) which are subject to all zoological rules like taxa. Such names applied to paragenera, paraspecies, etc., would not be transferable to correlative taxa used for whole animals. Procedure for establishing nomenclature of parataxa is outlined.

* Person presenting paper.

3. SIGNIFICANCE OF LIVING FORAMINIFERAL POPULATIONS ALONG THE CENTRAL TEXAS COAST

FRED B. PHLEGER

Scripps Institution of Oceanography, La Jolla, California

Living foraminiferal populations have been studied from San Antonio, Mesquite, and Aransas Bays and from numerous open-ocean samples across the adjacent continental shelf. This work is a part of A.P.I. Project 51.

Living populations in the bays average 50–200/10 ml. wet sediment at most stations. They are considerably higher in upper San Antonio Bay than elsewhere and are largest off the delta of the Guadalupe River. The total populations (dead and living) are unusually high, most stations having more than 10,000/10 ml. wet sediment. Low living populations at some stations appear to be related to conditions of deposition. The living population shows the same biofacies pattern as the total population.

Living populations on the continental shelf are approximately the same size as in the bays. Marked faunal boundaries occur at 10–20 m. and 40–60 m. Less distinct boundaries occur at a variety of other depths. Living and dead distributions are similar except that dead specimens tend to be more widespread downslope than living ones. Shallow depth ranges are more reliable than deep ones.

Relative rates of deposition are suggested by ratios between live and total populations. These data suggest that sedimentation is relatively fast near the Guadalupe River and is very slow in the lower bays. Rates are intermediate on much of the shelf and very low on the outer shelf. High populations of Foraminifera seem to indicate a slow rate of terrigenous deposition.

4. PALEOECOLOGY OF THE FLORIDA MIOCENE*

HARBANS S. PURI† AND ROBERT O. VERNON

Florida Geological Survey, Tallahassee, Florida

The type section for the Miocene in southeastern United States is in West Florida, where these rocks are divided into three Stages: Tampa, Alum Bluff, and Choctawhatchee.

The Tampa Stage is divided into two lithofacies: the calcareous St. Marks facies and the silty Chattahoochee facies. The Chattahoochee facies was deposited in moderately shallow warm water in a pro-deltaic environment where clastic sedimentation was going on. Downdip the calcareous St. Marks facies was deposited in deeper water where more calcium was available.

The Alum Bluff Stage is subdivided into four lithofacies: Oak Grove, Shoal River, Hawthorn, and Chipola. The Oak Grove facies was deposited

* Publication authorized by the Director, Florida Geological Survey.

† Person presenting paper.

in a localized shallow marine-to-brackish water transgressive-regressive phase of the Alum Bluff sea. The Oak Grove sediments are mostly sandy and sparsely fossiliferous and have yielded a microfauna which is similar to that common in the modern brackish-water bays. Downdip the Shoal River sediments are predominantly sandy with some intervening shell marl beds. The dominant fauna of these sediments is typically brackish as shown by the predominance of *Streblus beccarii, Elphidium gunteri, Anonocytheridae* sp., *Haplocytheridea bassleri* and *Perisso-cytheridea matsoni*, among other brackish water species. A slight influx of inner neritic forms is also present in the Shoal River. These inner neritic forms, though not living in modern bays, are represented by the empty tests and carapaces which are washed into the bays from the open sea at high tides.

The transgressive Alum Bluff sea moving over the sediments of the Tampa Stage deposited Chipola sediments. Both the organic tests and precipitation of calcium carbonate contributed to the calcareous nature of the Chipola facies. The Chipola microfauna is indicative of warm water (20–30°C.) conditions, and the bulk of the Chipola facies was deposited in a depth range of 110 meters.

The Hawthorn facies in West Florida consists of a continental subfacies that occurs around the Alum Bluff area. The sediments in this continental facies are composed of coarse-to-fine sand and some silt, with abundant impressions of fossil leaves. In the area west of the Alum Bluff and around Tallahassee, the Hawthorn facies is represented by the deltaic subfacies. This deltaic subfacies consists of variegated, massive-to-crossbedded sands, pebble conglomerate, and fuller's earth deposits. These deltaic sediments, whenever fosiliferous, yield a meager fauna of *Streblus beccarii* var. and species of *Elphidium*. This subfacies fans out into northern and western Florida from a point at the Georgia-Florida line north of Tallahassee. The marine subfacies outcrops in Columbia County and Alachua County, and occurs in subsurface in South Florida, where most of the section is shallow marine and consists of several shell beds with abundant oyster and *Pecten* shells deposited in a near-shore calcareous environment. This subfacies is stratigraphically lower than the phosphate subfacies that crops out in Alachua County and in the phosphate district. In northern Florida, the Hawthorn facies is overlain by beds of Choctawhatchee age, which have formerly been called Nassau marl. In West Florida, except in the Tallahassee Hills, the Hawthorn is overlain by sediments of Choctawhatchee. In the Central Highlands, the Hawthorn laps on beds of Ocala age. Throughout the rest of the State, the Hawthorn is overlain by the Choctawhatchee sediments.

The Alachua facies is the terrestrial equivalent of the Hawthorn in central and northern Florida, where these beds carry a middle and upper Miocene vertebrate fauna, silicified wood and basal rubble of phosphate rock. These sediments occur in solution pits, sinks and valleys along northwest-southeast trends that parallel the Ocala uplift.

The Choctawhatchee Stage is subdivided into four biofacies in West Florida: *Yoldia, Arca, Ecphora* and *Cancellaria*. The *Yoldia* facies represents the westernmost shallow-water marine sediments of the Choctawhatchee, deposited locally in the vicinity of the type locality. The microfauna is indicative of shallow (10–110 meters) water inner neritic conditions. Downdip, the *Arca* facies microfossil assemblage is indicative of depth zone between 30 and 100 meters. The bulk of *Ecphora* and *Cancellaria* facies, which is transgressive-regressive in nature, seems to have been deposited between 128 and 200 meters. The upper portion of the *Cancellaria* facies, which overlies the *Ecphora* facies in places, was deposited under more shallow conditions.

Tamiami facies in South Florida is a lithologic and faunal equivalent of the *Ecphora-Cancellaria* facies of West Florida. Downdip, in the South Florida Embayment area, Tamiami intergrades into the *Arca* facies. The *Arca* facies of the South Florida Embayment area was deposited under similar conditions as its counterpart in West Florida.

5. SEDIMENTARY REFLECTIONS OF THE DEPOSITIONAL ENVIRONMENT IN A COASTAL LAGOON

HARRIS B. STEWART, JR.
Scripps Institution of Oceanography, La Jolla, California

Samples of the bottom sediments and overlying water from San Miguel Lagoon in Baja California, Mexico, show that striking horizontal and vertical sediment variations are reflections of comparable areal and temporal variations in the environment. Particle-size distributions interpreted in terms of depositional processes reveal the lagoonward extent of ocean-derived sediments deposited by tital action, washovers, and wind action. River-derived material extends well seaward of the lower limit of the river environment in the water at the time of sampling, probably reflecting flood deposition. Living plants and animals are abundant, but a maximum of only 1 percent organic material was found in black muds rich in H_2S. Lowest oxygen values occur in the water overlying these black muds, probably related to the high rate of organic decomposition. Diurnal variation graphs of dissolved oxygen and pH are compared with values obtained from water samples taken at different times of the day and used to delineate 5 aqueous environments within the lagoon. These environments correlate with the underlying sediments in the areas where deposition was taking place at the time the water was sampled. The water samples were obtained while the bay barrier isolated the lagoon from the ocean and no tidal currents operated in the lagooon. The river at that time was not in flood. Hence the sediments deposited primarily by tidal action and those deposited by floods do not reflect the water overlying them at the time of sampling.

Criteria are discussed for recognition of ancient lagoon deposits in the geologic record.

6. RECENT AND ANCIENT PENETRANTS

MAXIM K. ELIAS
University of Nebraska, Lincoln, Nebraska

Some microscopic plants and invertebrates settle upon the surface and bore into the walls of various larger organisms, or some of these let the growing walls engulf them. Their presence is revealed in the course of detailed morphologic and anatomic study of the skeletons of living and fossil invertebrates. Besides the better-known clinoid sponges and the boring algae, minute ctenostomatous bryozoans penetrate not only molluscan, but also some benthonic foraminiferal tests of Tertiary to Recent age. Equally small plants, probably fungi, penetrate the tests of some pelagic foraminifers, whereas other enigmatic plants are attached to and penetrate the walls of some ramose cyclostomatous and trepostomatous bryozoans ranging in age from Ordovician to Recent. Some puzzling structures in and upon the walls of brachiopods, bryozoans and corals may be the result of activity by some penetrants.

7. MARINE ECOLOGY AS AN AID IN THE TEACHING OF INVERTEBRATE PALEONTOLOGY AND STRATIGRAPHY

WILLIAM H. MATTHEWS III
Lamar State College of Technology, Beaumont, Texas

Academic institutions located near the coast have at hand an excellent outdoor laboratory for students of invertebrate palontology and stratigraphy.

A study of various marine habitats enables the student to observe (1) a variety of ecological situations, (2) the organisms inhabiting them, (3) adaptations of these organisms to different environments, and (4) their effect on sedimentary environments.

On Galveston Island, Texas, the following habitats may be conveniently studied:

1. *Rocky shore.*—At Galveston this is a man-made environment resulting from the construction of a pair of stone jetties. Wave action, scour and salinity variations are important factors in this environment.
2. *Sandy beach.*—The beaches support relatively few organisms, but burrowing pelecypods and gastropods are found along the strand. Many dead shells of animals inhabiting the sands extending from the shore may also be collected on the beaches. These specimens are useful for comparative material in paleontology.
3. *Mud flat and brackish water.*—Forms typical of this habitat may be studied with respect of environment adaptation.
4. *Near-shore bottom.*—Many neritopelagic and nektoplanktonic forms may be collected by means of a small dredge.

The above habitats support interesting faunas representing different sedimentary and biological environments. A comparison of these faunas reveals many examples of faunal zonation, environmental adaptation and evolutionary diversification. Studies of this type introduce the student to the paleoecological approach in the solution of paleontological and stratigraphic problems.

The marine field trip should be followed by a geological field trip and an effort made to correlate the results of the two studies. Written reports are required for both the ecological and geological trips.

Wednesday, April 25, 9:00 A.M.
Waldorf Ballroom, Hilton Hotel

SYMPOSIUM: PALEOECOLOGY

Presiding: H. S. LADD, U. S. Geological Survey, Washington, D. C., AND BERNHARD KUMMEL, Harvard University, Cambridge, Massachusetts

1. INTRODUCTORY REMARKS

ROBERT R. SHROCK
Massachusetts Institute of Technology, Cambridge, Massachusetts

2. PLAN OF SYMPOSIUM

HARRY S. LADD

3. MARINE LEVEL-BOTTOM ANIMAL COMMUNITIES OF RECENT SEAS

GUNNAR THORSON
Copenhagen Zoological Museum, Copenhagen, Denmark

Out of the 850,000 species of Recent animals, 140,000 (16%) only are marine. Some of these

are planktonic, the majority is associated with rocks and vegetation, and the rest with sandy and muddy bottoms. This means that the level-bottom areas of the sea, though covering more than half the surface of our globe, are inhabited by only 2–3 percent of all Recent species of animals. Quantitative samples from several seas prove that the same types of level-bottom substrata at similar depths are dominated by invertebrates belonging to the same genera but to different species, thus forming chains of "parallel communities" in all seas, arctic and tropical, and being adapted to the temperatures of the latitudes in which they live. The metamorphosing pelagic larvae are able to respond positively or negatively to a bottom substratum. and this substratum seems to be the main factor responsible for their settling and, accordingly, for the qualitative composition of each level-bottom community. In the open sea a muddy bottom will normally be an indicator of calm water, i.e. greater depth, stable temperature and salinity, whereas a bottom covered with coarse sand means turbulent water at shallower depth, i.e. larger fluctuations in temperature and salinity. The substratum, directly responsible for the composition of the animal community, thus at the same time tells us a good deal about the local ecological conditions. Recent level bottoms are dominated by astonishingly few genera and species, which one day will be the geological guide fossils for our period.

4. CONDITIONS OF LIFE IN THE SEA

JOEL W. HEDGPETH
Scripps Institution of Oceanography,
La Jolla, California

Although the volume of the sea is several hundred times that of the terrestial environment (including lakes), most of the consideration of ecological factors and ecological theory have been built around our knowledge of the terrestrial environment, which lacks the three dimensional, fluid nature of the marine environment. It has been said that sea water is an "organic puree," and one of the most pronounced differences between the life of the sea and that of other environments is the abundance of organisms in the sea that are adapted to feed upon finely suspended and colloidal material. Another major difference between sea and land in particular is the manner in which the products of organic activity (such as vitamins and antibiotic substances) are suspected to affect other populations in the sea on a large scale, again a reflection of the ambient, three dimensional medium that is the sea. Whether life in the sea proceeds at a more or less efficient pace than on land is at present an open question, but it does appear that most food chains in the sea are longer and more involved than on land, an indication, perhaps, that the greater space provided by the sea in turn provides more niches, as well as a greater dispersal of materials through the environment. It is inadvisable to apply the major concepts of terrestrial ecology to the sea without careful thought, since such concepts as succession and climax have been built around the interaction of climate and biota, with climate playing the controlling role, whereas the character of the marine climate (understood as prevailing conditions) is as yet inadequately understood. A case in point is the argument whether certain bottom organisms actively select a type of sediment because of some organic substance in it or whether both organisms and sediment type are where they are because of common hydrographic conditions.

5. PALEOECOLOGICAL EVIDENCE FURNISHED BY FOSSILS

HARRY S. LADD
U. S. Geological Survey

The shape of a fossil or the structure of its shell—external or internal—may give a clue to the mode of locomotion of nektonic or benthonic types and may suggest the general habitat of either sedentary or pelagic forms. In some instances the position of a shell in the rock or the perfection of its preservation may indicate or even demonstrate that it was buried where it lived. Many of the most highly populated marine areas, however, are not sites of deposition and it is evident that many fossil shells were transported prior to final burial. This may be shown clearly by incomplete or worn fossils, in assemblages containing both marine and brackish or fresh water types or in assemblages containing fossils of widely different ages. Fossil faunas in which elongate shells are uniformly oriented or in which there appears to have been selective sorting may be indicative of wave or current action. Preservation of color or traces of a color pattern may suggest the depth at which the animal lived and, perhaps, the orientation of its shell in life. Chemical studies of the composition of shells that appear not to have been altered by the passage of time may reveal much about the temperature or other features of the original environment. Concentrations of fossils on a single bedding plane may suggest catastrophic death due to one of several causes.

All paleoecological interpretations based on fossils must, however, be made with caution, particularly those involving extinct groups or forms that have no close living relatives.

6. PALEOECOLOGICAL EVIDENCE FROM SEDIMENTS

BERNHARD KUMMEL
Harvard University, Cambridge, Massachusetts

Much information about the environments of fossil organisms may be obtained from the rocks that contain the fossils. Texture may reveal a good deal about the type of bottom, the clearness or turbidity of the water, possibly even the depth of deposition; certain fabrics seem to characterize specialized sedimentary environments. The occurrence of graded bedding may be most revealing, particularly if it can be related to changes in faunal content. Certain types of black shale are formed in areas where there is a dearth of oxygen

and organic matter is accumulated faster than it can be oxidized.

Sedimentary structures such as ripple marks that persist laterally or vertically may be used to support broad generalizations involving oceanic circulation. Other markings, such as cross-bedding, are indicative of shallow depths or other specialized conditions.

The occurrence of a high content of calcium carbonate, including oolites or concentrations of glauconite, phosphorite or nodular manganese may also be used in interpreting past environments.

7. DIATOMS AS PALEOECOLOGICAL INDICATORS

KENNETH E. LOHMAN

U. S. Geological Survey, Washington, D. C.

Diatoms, by virtue of the minute size and durability of their siliceous shells, are widespread over the globe, and occur in many types of sediments deposited in marine, brackish, or freshwater basins. Many species prefer rather restricted temperature ranges, from pools in ice floes at one extreme to hot springs at the other. They are readily trasported in reproductive condition over long distances by ocean currents, wind, birds, and other agencies, with the result that at any one period of geologic time a group of species adjusted to a particular environment can be found anywhere in the world where that environment exists. Furthermore, any assemblage of fossil diatoms found, particularly in Tertiary rocks, contains a mixture of extinct species and those still represented in living assemblages.

This fortunate combination of properties renders the diatoms exceptionally useful for paleoecological interpretations, as well as for stratigraphic correlations.

Marine diatoms are now known from rocks of late Mesozoic to Recent age; non-marine diatoms from rocks of Oligocene to Recent age. The completeness of the earliest known assemblages, and their degree of diversification, however, strongly suggest that diatoms, both marine and nonmarine, must have lived in still earlier geologic periods.

The criteria used in the taxonomic classification of these organisms, both living and fossil, are based upon the shape and intricate structure of the siliceous shell, and not on the ephemeral soft parts. This is particularly advantageous for paleoecological interpretations as it reduces the possibility of confusion between the biologist working with the living diatoms and the paleontologist using the fossil ones. It thus has the effect of welding the literature on Recent diatoms with that of the fossils into one harmonious continuum of data equally intelligble to biologists and paleontologists.

8. NEW TECHNIQUES IN PALEOECOLOGY

PHILIP H. ABELSON

Geophysical Laboratory, Carnegie Institution of Washington, Washington, D. C.

Physical and chemical studies of fossils are revealing new types of information concerning paleoecology and paleobiochemistry. Measurements of O^{16}/O^{18} ratios in calcareous fossils by Urey, Lowenstam, Epstein, and McKinney yielded paleotemperatures and have permitted examination of life cycles of some organisms.

Organic constituents have been found in many fossils. Amino acids, including alanine, glutamic acid, glycine, isoleucine, proline, and valine, have been found in a specimen of the armored fish, *Dinichthys terrali*, from the Devonian Ohio black shale. Laboratory studies indicate that many other chemicals of biological origin have sufficient stability to endure for equally long periods of time.

This talk will review briefly the present status of these new developments and point out further opportunities for study.

Wednesday, April 25, 1:45 P.M.

Waldorf Ballroom, Hilton Hotel

MINERALOGY AND SEDIMENTARY PETROLOGY

Presiding: LEWIS CLINE, University of Wisconsin, Madison, Wisconsin, AND ELY MENCHER, Massachusetts Institute of Technology, Cambridge, Massachusetts

1. UNIFORMITARIANISM IS A DANGEROUS DOCTRINE

PAUL D. KRYNINE

The Pennsylvania State University, University Park, Pennsylvania

Geologic extrapolation into the past is vitiated by:

1. *Immediate causes*
   a. Post-glacial phenomena are geologically abnormal, as they form less than 2 percent of Post-Cambrian history—excessive periglacial and desertic eolian activity, aridity, etc.
   b. Common mistake of misinterpreting *fossil* glacial and *pluvial* phenomena as being recent (pluvial red soil or alluvial fans in young post-glacial deserts, etc.)
2. *Intermediate causes*. Large-scale emergence of continents, excessive since Permian and particularly Pleistocene. Results are:
   a. Considerable decrease of *shallow* epicontinental seas and related large-scale, inorganic limestone-dolomite and orthoquartzite deposition; converse increase in size of deltas, with drastic textural changes in detrital sediments.
   b. Changes in basic morphology and sedimentary performance of geosynclinal

basins from Paleozoic into Tertiary. Older geosynclines generally restricted between rigid crystalline shield segments (so called "kratonic" pieces) or, although located on subsiding plastic (so called "mobile") continental borders, nevertheless almost landlocked (sedimentationally "closed") by smaller land-masses (e.g. Appalachian trough) and furthermore *connected* with shield-covering (so called "kratonic") epicontinental seas. Tertiary and recent basins occur mostly on extreme borders of continents, abutting against oceanic abysses (sedimentationally "open"). This has changed all principal textural and compositional modes of both carbonates and graywackes.

3. *Ultimate causes.* Increase in rate (tempo) and change in morphology of tectonic deformation since early Paleozoic toward a more intermittently frequent distribution and a basic upward tendency. Results, besides physiographic emergence of continents, are increase in abundance of actively eroded crystalline massifs (as against slate-phyllite source areas) and predominance of erosion over chemical weathering—mean feldspar content of Paleozoic sandstone less than 5 percent; of Mesozoic-Tertiary more than 20 percent with accompanying kaolinite increase; conversely mean phyllite-slate fragment content of Paleozoic sandstones more than 20 percent as against 10 per cent in Tertiary, with corresponding decrease in illite. A similar change occurs also in the heavy accessory suite. These changes are qualitative and abrupt, i.e. result from different provenance, rather than quantitative and gradual (i.e. due to gradual intrastratal alteration). No age alteration will transform a piece of granite inside a sediment; nor will the kaolinitic matrix of a sediment be transformed through age into a piece of large, sand size, perfectly recognizable fragments of illite-slate, complete with internal structure and clear-cut boundaries. Conventional uniformitariansim or "gradualism," i.e. the doctrine of unchanging change is verily contradicted by all post-Cambrian sedimentary data and the geotectonic histories of which these sediments are the record. Thus quantitative interpretations of the Ordovician from the Recent are meaningless.

2. TERTIARY REEF LIMESTONES FROM SOUTHERN LOUISIANA AND GUAM

McLain J. Forman* and Seymour O. Schlanger

c/o Gordon Atwater, Consulting Geologist, New Orleans, Louisiana; U. S. Geological Survey, Washington, D. C.

Striking similarities in fossil content and lithology in reef limestones from southern Louisiana and Guam indiate that biologically similar reefs existed in these two areas during Tertiary time. The reefs in southern Louisiana are largely restricted to *Heterostegina* zone strata of Oligocene age; the Guam reefs are of lower Miocene age.

Topographic highs formed by intrusion of piercement-type salt domes afforded favorable conditions for local reef growth in portions of southern Louisiana, whereas a more extensive reef developed on a shallow-water shelf area in extreme southeastern Louisiana. An older volcanic ridge and the flanks of an intermittently active submarine volcano were the sites of reef growth at Guam.

Rock types common to both areas are: (1) poorly sorted conglomerates consisting dominantly of algal and coral fragments, tests of foraminifera, and mollusk shells, all cemented by encrusting algae and foraminifera; (2) well-sortedc onglomerates and calcarenites made up of tests of foraminifera and fragments of articulate and encrusting algae in a fine-to-medium grained matrix; and (3) foraminiferal calcarenites containing large benthonic types and small pelagic types in a fine-grained matrix.

These three rock types are interpreted respectively as indicating deposition in: (1) shallow-water, reef and near-reef environments; (2) fore-reef or back-reef areas, below depths at which coral and encrusting algae flourish; and (3) deeper waters beyond the zone of reef-detritus deposition in areas where pelagic foraminifera contributed significantly to bottom deposits.

These similarities in rock types and facies associations illustrate the tendency of reefs to develop in characteristic patterns on submarine topographic highs, regardless of the original substrate.

3. THE MINERALOGY OF THE FUNAFUTI DRILL CORES AND ITS BEARING ON THE PHYSICOCHEMISTRY OF DOLOMITE

Robert F. Schmalz

Belmont, Massachusetts

The mineralogy of cores from Funafuti atoll was of considerable importance in the formulation of theories of dolomitization. The original analyses were made by methods which today appear unreliable however, and the present study re-examined the cores by x-ray diffraction techniques.

The distribution of carbonate mineral species was confirmed, in general, by the present study. (1) Aragonite, common near the surface, diminishes in abundance with depth and vanishes below 220 feet. (2) Dolomite, entirely absent in the upper portion of the core, is dominant and universally present below 640 feet. (3) Calcite, the dominant mineral at depths less than 640 feet, appears only in thin horizons below the point where dolomite is first found. (4) The magnesium-rich horizon near the top of the core is due not to the presence of dolomite, but to magnesium in metastable solid solution in calcite.

The systematic distribution of mineral phases revealed by the present study admits of physico-

* Person presenting paper.

chemical interpretation. It is proposed that porous limestones of the atoll are in chemical equilibrium with sea-water at all depths. The chemical system, limestone plus sea-water, lies in the stability field of calcite plus magnesium-ion above 640 feet; below this level, probably due to increased hydrostatic pressure, dolomite is the stable phase.

Unstable organically precipitated phases, aragonite and high-magnesium calcite, persist in depth beneath the zone of organic activity due to their slow rate of reaction to the stable phase.

Tentative sub-solidus phase diagrams conforming to these data are discussed.

4. HEAVY-MINERAL ASSEMBLAGES OF THE CORAL-REEF LIMESTONES AT THE BASE OF THE TRICHINOPOLY CRETACEOUS (CENOMANIAN TO DANIAN), SOUTH INDIA

C. GUNDU RAO

The Pennsylvania State University, University Park, Pennsylvania

Thirty samples representing the southern and northern facies of the coral-reef limestones at the base of the Trichinopoly Cretaceous (S. India), and eight samples of the Cullygoody limestones occurring along the southeastern border of this area were subjected to heavy mineral analysis and the following minerals recognized: magnetite and ilmenite, tourmaline, hornblende, epidote, staurolite, kyanite, garnet (colorless and pink), zircon, rutile, enstatite, hypersthene and apatite. Magnetite and ilmenite, and garnet (colorless and pink) form the main assemblage.

Although the heavy minerals in the different exposures of the coral-reef limestones are generally similar, the Naicolum ridge and the basal part of the Terany ridge of the Southern facies, show a poor concentration of garnets. The heavy mineral assemblage of the coral-reef limestones differs from that of the underlying upper Gondwana plant-bearing beds in being poor in zircon and rutile, and practically devoid of tourmaline. The heavy mineral assemblage of the Cullygoody limestone differs from that of the coral-reef limestones in being rich in zircon and rutile. It resembles that of the upper Gondwana rocks of this region in being rich in zircon and rutile but differs from the same in being poor in epidote and practically devoid of tourmaline.

Statistical studies in the zircons of the (1) coral-reef limestones and the (2) Cullygoody limestone has shown that both of these limestones include zircons of two generations. The first generation zircons in the coral-reef limestones may be explained as directly derived from the original source rocks, whereas the second generation ones seem to have been reworked from the underlying upper Gondwanas. But in the case of the Cullygoody limestone the occurrence of second generation zircons is difficult to explain in view of the absence of any known upper Gondwana rocks or any other sedimentary formation underlying this limestone.

The latter part of the paper presents the results of some statistical investigations on the lines of Smithson in his studies on the Triassic and Jurassic rocks of Yorkshire.

The ultimate source of the detritus in these limestones seems to have been in the charnockites, granites and gneisses lying to the west and south of the area.

5. PETROGRAPHY AND GENESIS OF THE OGALLALA "ALGAL LIMESTONE" IN KANSAS AND ADJACENT STATES

ADA SWINEFORD,* JOHN C. FRYE, AND A. BYRON LEONARD

State Geological Survey of Kansas, Lawrence, Kansas; Illinois State Geological Survey, Urbana, Illinois; University of Kansas, Lawrence, Kansas

Petrographic study of 34 oriented samples of "Algal limestone" from the upper part of the late Tertiary Ogallala formation in Kansas, Oklahoma, and west Texas indicates that the rock sampled was developed predominantly by soil-forming processes acting upon sands and silts of the uppermost Ogallala. The absence of fossils (especially diatoms, which invariably occur in all other limestones examined from many levels in the Ogallala), replacement of sand grains by calcite, anomalous distribution of detrital grains with respect to oolites and bulbous structures, and the inverted orientation of the bulbous structures themselves, all argue against algal origin of the rock. Presence of as much as 2 percent barite in veins cutting across concentric laminae suggests increase of sulfate ion during periods of excessive aridity.

The origin of the limestone is similar to that of the old caliche in southeastern New Mexico described by Bretz and Horberg, except that limestone gravels were not required for its formation. The concretionary structures are analogous to those formed in bauxites in the zone of concretion. Conditions favoring development of "Algal limestone" were (1) presence of rocks with easily soluble minerals yielding residues rich in Ca^{++} ion; (2) effective rock permeability; (3) deficient rainfall and long dry periods; (4) low topographic relief; and (5) time.

6. SHELFEDGE, CALCAREOUS PROMINENCES IN THE NORTHEASTERN GULF OF MEXICO

JOHN C. LUDWICK† AND WILLIAM R. WALTON

Gulf Research & Development Company, Houston, Texas

A survey of the topography, sediments, and faunas in the northeastern Gulf of Mexico has demonstrated the presence of a belt of calcareous, reef-like features near the edge of the continental

* Person presenting paper.
† Person presenting paper.

shelf between 40 and 55 fathoms. The zone of prominences is approximately one mile wide, discontinuous with 10–20 mile gaps, and has an average relief of 30 feet.

A detailed study has been made of a five-square-mile section of this feature at the edge of the shelf south of Mobile, Alabama. The sedimentary and faunal characteristics of the deposits form natural groupings that can be correlated with submarine topography, past and present ecological conditions, and history of the region.

This reef is intermediate in stage between active growth and fossilization and possesses some characteristics of both stages. Past and present processes and environments, both subaqueous and subaerial, have tended to distribute and modify the sediments and faunas so as to present a complex pattern of indigenous, relict and reworked sedimentological characteristics in the area today.

The reef flourished under previous environmental conditions of shallower, possibly warmer, waters. It has not survived a rise in sea level and is now undergoing slow modification by after-growth and self-burial. The probability is high that this feature will be preserved in the geologic column. In some characteristics, it resembles known ancient reefs.

7. SILURIAN REEFS OF THE NORTHERN EDGE OF THE EASTERN INTERIOR BASIN

JOHN B. SANGREE, JR.
Northwestern University, Evanston, Illinois

A study of the reefs in the Silurian outcrop region of northern Indiana and northeastern Illinois indicates a rough morphological classification of the reefs into: (1) broad, horizontally bedded reefs, (2) intermediate reefs with large flat tops and steeply dipping marginal talus beds, and (3) isolated reefs composed of a high narrow central core surrounded by talus beds. These reef types are gradational and numerous subdivisions are possible. Characteristic lithologies are associated with each type. Type 1 is distinguished by a varied, robust fauna, commonly associated with oolitic beds. The horizontally bedded rocks found on the flat tops of reef type 2 are very similar to the lithology of type 1. The steeply dipping reef-derived flank beds vary from conglomeratic to sand-sized coquinas. Reef type 3 consists of coarse, obscurely bedded fossil-fragmental core rocks, combined with flank rocks which vary widely in texture and fauna, depending on growth conditions. The major factors controlling reef differentiation in this region are depth, turbidity, salinity, and nutrient supply of the sea, and topography and tectonic stability of the substrate. Characteristic associations occur between reef and inter-reef beds, indicating some modification of the off-reef environment by the reef proper. The complexity of these associations are largely responsible for the difficulties of correlation encountered in areas of reef growth. A better understanding of environmental associations should lead to more satisfactory correlations.

8. TRANSITIONAL PERMO-PENNSYLVANIAN SEDIMENTS OF THE ROWE-MORA BASIN, NEW MEXICO

RAYMOND SIDWELL AND G. FREDERICK WARN*
Texas Technological College, Lubbock, Texas

These sediments vary in thickness from approximately 50 feet in the southern part of the basin to 3000 feet in the northwest portion. They were deposited in a post-geosynclinal environment, beginning on an unstable shelf in late Pennsylvanian. Shelf deposits were transitional from marine to continental, becoming dominantly continental in the Permian and eventually returning to marginal marine in late Permian (Yeso and San Andres). Surrounding highlands influencing sedimentation included the Front Range, Uncompahgre-San Luis Uplift, Pederenal Range and Sierra Grande-Las Animas Arch. Control was exerted locally by basement-complex islands. The positive areas were uplifted in late Pennsylvanian and early Permian and were progessively lowered by erosion during middle and late Permian time. Clastic rock types and their heavy-mineral content suggest source areas that were predominantly igneous (granitic) but which included mildly metamorphic rocks.

The Transition Beds consist mainly of a red-bed sequence. The Pennsylvanian portion of the Transition Beds includes thin, impure limestones and marls; minor amounts of arkosic limestone; micaceous, sandy shales and clays; and arkosic, calcareous sandstones and conglomerates. These pass laterally and/or upward into probable Wolfcampian deposits of limy, arkosic coarse sandstones and conglomerates characterized by wedging and cross-bedding. Massive conglomerates with rounded quartz pebbles and subangular quartzite pebbles and cobbles occur above the arkosic section. These are followed by variable arkoses and micaceous, calcareous clays and sandy silts and shales. Marls tend to be conspicuous in most of the section. Sandstones in the lower and upper thirds of the section are notably calcareous.

Heavy minerals in $\frac{1}{2}$ to $\frac{1}{16}$ mm. grain sizes appear in the following order of abundance in the lower Transition Beds: magnetite, mica, tourmaline, garnet, zircon, hornblende and rutile. The order of abundance in the upper Transition sequence is: magnetite, garnet, mica, tourmaline, zircon and rutile.

* Person presenting paper.

Thursday, April 26, 9:00 A.M.
Waldorf Ballroom, Hilton Hotel

MINERALOGY AND SEDIMENTARY PETROLOGY

Presiding: HAROLD N. FISK, Humble Oil and Refining Company, Houston, Texas, AND HAYDN H. MURRAY, Indiana University, Bloomington, Indiana

1. ALICE IN GRAYWACKELAND

PAUL D. KRYNINE

The Pennsylvania State University, University Park, Pennsylvania

A recent eruption of "graywacke" papers (Bockman; Dapples, Krumbein and Sloss; Folk; Gilbert et al.; Kuenen; Packham; Pettijohn; Tallman; Travis; etc.) plus a rush for turbidity currents threatens to give petroleum geologists the usual hangover that follows the hasty misuse of poorly understood exploration methods. Indeed:

1. There are *four* major detrital rock series (or "clans") depending upon *inherited* mineral composition. These are orthoquartzites, low rank or common graywackes, high rank or feldspathic graywackes, and arkoses. They are respectively related (Krynine 1941–1955) to geotectonic types I and I_m; II_d and II_f; III and IV.
2. Types I, II, and IV may show internal mineralogic and textural development sequences, either strictly positional, or conventionally chronologic (so called "maturing," a somewhat loose term).
3. *All major types* may contain "silty or clayey" and "poorly sorted" *bimodal* rocks fully analogous to igneous porphyries. These may show graded bedding irrespective of rock type.
4. *Low rank or common graywackes* are very low in feldspar (less than 10 percent as a mean), and carry *enromous* initial loads of micas and hydromicas, either as discrete particles ("clay") or as slate-phyllite-schist rock fragments. They are thus skewed toward the finer sizes, complete with all derived second- and third-order properties. Genetically these are basically shallow water, near-shore sediments. Turbidity currents, if any, are within *ordinary deltas*. Low rank graywackes are totally *primary* (not the product of sequential differentiation of any other rock type!). They probably contain most of the oil and are the most abundant single sedimentary rock.
5. *High rank or feldspathic graywackes* are both primary and *terminal* at the same time. They are the only sedimentary rock series that shows *no* development sequence and are thus *not* ancestral to subgraywackes (Pettijohn 1949) or to arkose (Pettijohn 1954). These rocks are rare (fortunately) and are petroliferously bone dry.
6. The term graywacke, in its proper petrographic (i.e. mineral compositional) sense, was used by Lyell before 1839, by Nauman in 1850, and was revived in its classical sense by Krynine in 1937, thus giving him priority in the modern usage of the term.
7. "Sedimentary porphyries" cut across *all* major rock types; arkoses may carry 35 percent of kaolinitic matrix and quartzites 20 percent of quartzoes silt matrix. Hence it is against scientific principles. as done by some of the writers mentioned above, to refer to such a porphyry as a "graywacke" (regardless of composition) and in the next breath to call a micaceous sediment also a graywacke (regardless of texture). Thus the textural usage of the term "graywacke" is rejected. The name graywacke was and should remain a first order, i.e. compositional, term. Texturally poorly sorted, bimodal rocks are porphyries and nothing else!
8. The term "subgraywacke" is even more confusing, having been founded on the genetic misconception that type III leads to type II. Being symbolic of this confusion it is also rejected. So is the term "lithic graywacke," because the basic variable is mica, not rock fragments.
9. Detailed petrographic work by this writer on ancient sediments from all parts of the world and on recent deep sea sands from the Atlantic contradicts the idea that graywackes (in any sense, either compositional or porphyritic!) were formed on any large or even moderate scale in highly viscous fluids, alleged to be turbidity currents. Furthermore, a critical examination of Kuenen's technique in his famous turbidity current experiment opens its validity to the gravest doubts.
10. Finally it must be understood that upon the four basic compositional detrital rocks there may be superimposed an enormous number of local textural variations. These are the "phases" of Krynine's sedimentary "systems" (1955), which can be finally reduced to Otto's sedimentary units. The geotectonic control of the emergence, preferred associations and effectiveness of these sedimentary loci is marked, but definitely indirect. This is the "determining background" concept of Krynine (1947). Oversimplifications in this field of the so-called depositional "sedimentary tec-

tonics" are dangerous and considerable overhauling is needed.

2. PETROLOGIC ANALYSIS OF A STRATIGRAPHIC TYPE OIL FIELD IN WEST CENTRAL TEXAS

MORTON K. BLAUSTEIN
Baltimore, Maryland

The Lindemann (McMillan Sand) Oil Field, Runnels County, Texas, is located on the Eastern Platform of the Midland Basin. It contains two separate reservoirs, the Upper and Lower McMillan sandstones of Cisco (late Pennsylvanian) age. Oil accumulation is controlled primarily by stratigraphic conditions.

The present study explores the possibility of determining the nature of oil accumulation in such a field by combining a detailed quantitative petrologic analysis of the reservoir rock with subsurface structural mapping.

The study is based on 309 thin sections from 43 wells. Approximately half of these thin sections are from five cored wells, the remainder being from drilling samples in wells which were not cored. The relative quality of these two types of thin sections is analyzed in detail and it is concluded that, in general, both types of material give excellent usable data.

Thin sections of the reservoir rock quite accurately reflect the productive potentialities ofs the unit. The sandstone, which includes a conglomeratic facies, is generally fine-grained to very fine-grained, and well sorted; the principal cements are calcite, quartz, and clay. Porosities and permeabilities are favorable for fluid transmissibility.

The principal trap-making elements in the Lindemann (McMillan Sand) Field are:

1. The updip pinchout of the reservoir rock.
2. Structural closure against this pinchout, caused by compaction of the reservoir rock and the underlying shales over a limestone reef.
3. Stratigraphic variations in the reservoir, petrologic in nature, which locally determine the productive and barren portions of the field area.

The petrologic parameters which act as porosity trap-making elements are (1) grain size, (2) grain-size sorting, (3) calcareous cement, and (4) clay cement. These parameters have been studied in thin section, reduced to quantitative data, and mapped. The maps explain the reservoir conditions and productivity of the Upper McMillan sandstone.

A retroactive analysis of the field, from the date of discovery, indicates that if the petrologic study had been made during the development of the field, it would have proved helpful in indicating directions in which to drill and in avoiding dry holes.

The author believes that if the method employed in this study is extended to the analysis of other fields and to dry hole failures between fields, it will eventually be possible to combine sufficient regional information to be useful in the effort to detect regional stratigraphic trends. Such new trends might point to favorable areas for exploratory drilling.

3. PERMEABILITY LOSS FROM SWELLING OF MATRIX CLAYS IN SUB-GRAY-WACKES

G. HARVEY HAMILTON AND GEORGE R. DOWNS*
Union Oil Co. of California, Denver, Colorado; Consulting Geologist, Denver, Colorado

Fresh water coming in contact with the matrix clays of subgraywackes causes the clays to deflocculate and reduce the permeability of the rock to a small fraction of its original value. This process may form a seal which is adequate to trap gas in the down-dip portion of an outcropping potential reservoir bed.

In the southern Piceance basin of western Colorado, gas has recently been discovered in a gentle syncline where no conventional type of structural or stratigraphic trap is apparent. In this area, surface waters freely come in contact with the outcrop of the producing beds. In the discovery well, a reservoir pressure ranging from 750 to 1000 pounds was anticipated, based on the projection of the hydrostatic gradient from the outcrop to the reservoir at the well bore. Actual measured pressures proved to be in excess of 2300 psi, demonstrating an effectively confined gas reservoir. There was no apparent lithologic difference between the rock in the reservoir and at the outcrop, except for the expanded matrix clay at the outcrop.

Laboratory core permeability determinations showed that the reservoir rock (a subgraywacke) had air permeability of 0.3 md. and 9.5% porosity. Upon artificial introduction of fresh water into the core plug, the permeability was immediately reduced to 0.0037 md. It is proposed that dipping, truncated, sub-graywackes may form an effective, but generally unrecognized type of stratigraphic trap—one which invites exploration. This method of gas entrapment provides a reasonable explanation for gas accumulation in certain fields, previously considered to be due to vaguely defined "permeability changes" in the reservoir rock.

4. DIFFERENTIAL COMPACTION OF PENNSYLVANIAN SEDIMENTS IN RELATION TO SAND-SHALE RATIOS, JEFFERSON COUNTY, ILLINOIS

JOSEPH C. MUELLER† AND HAROLD R. WANLESS
Continental Oil Company, Oklahoma City, Oklahoma; University of Illinois, Urbana, Illinois

In Jefferson County, in the Illinois coal basin, southern Illinois, the Pennsylvanian column

* Person presenting paper.
† Person presenting paper.

between the Shoal Creek and Stonefort limestones, an interval of about 900 feet, was divided into seven intervals separated by widespread coals or limestones readily recognized on electric logs, namely the Shoal Creek limestone, coal No. 8, West Franklin limestone, coal No. 7, coal No. 5, coal No. 4, coal No. 2, and the Stonefort limestone listed in descending order. These intervals were determined from 578 electric logs in the county, an average of about one per square mile. Sand-shale ratios were determined for each interval and it was found that a "channel" sandstone of one age occurs in each interval except between the Shoal Creek limestone and coal No. 8. Two ages of channels occur in one interval. Sand-shale ratio maps were made of each interval. Thicknesses of each interval were compared in the "channel" areas and nearby, outside the channel, to avoid regional variations in thickness. Assuming that the coals and limestones were laid down nearly parallel to each other, variations in interval result from greater compaction of the shales than of the sandstones. Results show the following percentages of differential compaction for the six intervals with channels listed in descending order: 21, 34, 29, 35, 42 and 54 percent.

5. CLAY-MINERAL COMPOSITION OF RECENT SEDIMENTS FROM THE MISSISSIPPI RIVER DELTA

W. D. JOHNS, JR.* AND R. E. GRIM
University of Illinois, Urbana, Illinois

Detailed clay mineral analyses of several hundred samples from the eastern and southern part of the Mississippi River Delta show montmorillonite as the most abundant component with smaller amounts of illite and chlorite or kaolinite. In general, the abundance of montmorillonite is highest in the river and near-shore samples and lowest in the off-shore samples. Modifications of this generality are presented and their possible causes are discussed.

The significance of the abundance of montmorillonite in relation to the character of the source area and the composition of other marine sediments is discussed. Consideration is given to the effect of differential flocculation, detailed variation in the source material, and diagenetic processes on the clay mineral distributions.

6. ENVIRONMENTAL CONDITIONS AFFECTING THE DEPOSITION OF BEACH SANDS BETWEEN VIRGINIA AND FLORIDA

SUZANNE F. BERSHAD† AND JOHN K. DUNCAN
Division of Oceanography, U. S. Navy Hydrographic Office, Washington, D. C.

The prime purpose of this study was to correlate observed environmental conditions with beach deposits by the collection of 127 beach samples at 48 locations along the Atlantic and Gulf of Mexico coasts between Cape Henry, Virginia and Panama City, Florida. Locations sampled were spaced at approximately 50-mile intervals. With each sample, observations were made of the slope, strike, and character of the beach and wind and wave states. The effects of tide stage and of land and submarine topography on beach deposits were studied. A detailed laboratory analysis of samples and sub-samples was made to determine their mechanical, mineral, and mass properties. The increase in shell content of the beach deposits from north to south substantiates previous studies of the Atlantic Coast beaches. Variations in median grain size between stratified layers of some samples were found to be as great as the variations between samples from widely separated locations, or from any part of the same beach profile.

7. MIDDLE PALEOZOIC TECTONIC HISTORY OF NORTH-CENTRAL AND NORTHWESTERN UTAH

JAMES E. BROOKS
Southern Methodist University, Dallas, Texas

Regional studies of middle Paleozoic stratigraphy in north central and northwestern Utah indicate the presence of two major tectonic elements which controlled the distribution and duration of areas of deposition and non-deposition and/or erosion in the area during this time interval. These elements were: (1) stable shelf, in the southeastern part of the discussion area in the region of the present western Colorado Plateau; (2) miogeosyncline, peripheral to the shelf on the north and west and separated from the shelf by a narrow transition zone. Localized areas of varying degrees of tectonism are recognized along the strike of the geosyncline.

The major hiatus which exists on the shelf between uppermost Devonian or lowermost Mississippian rocks and Cambrian strata obscures the tectonic behavior of the shelf during the intervening portion of geologic time. Study of several adjacent stratigraphic sections within the geosyncline demonstrates the existence of several hiatal breaks of much shorter duration. These breaks may be traced shelfward with increasing temporal values until they merge with the major shelf discontinuity. Similarly, rock units bounded by these hiatuses persist with little lithic change toward the shelf and are typically completely removed by erosion by the time the transition zone is reached. The regional extent and lateral change in duration of the hiatuses together with the extent and lithology of the intervening rock units constitute a valid basis for interpreting the tectonic behavior of the stable shelf during the time now represented by unconformity.

8. TRIASSIC IN THE EASTERN GREAT BASIN

DAVID L. CLARK,* AND WILLIAM LEE STOKES
University of Iowa, Iowa City, Iowa: University of Utah, Salt Lake City, Utah

New data concerning Triassic stratigraphy in

* Person presenting paper.
† Person presenting paper.

the eastern part of the Great Basin have been obtained from previously undescribed sections in the western Utah-eastern Nevada area. These sections contain information regarding the western Utah-eastern Nevada part of the Triassic miogeosyncline, its deformation, stratigraphic relations and associated fauna. The Triassic is the youngest marine sequence presently known in this area, and it lies disconformably on Permian strata. Overlying Tertiary and Recent rocks consist of volcanics and alluvial material.

The only definite Triassic age assignment in this area is established on the occurrence of the Lower Triassic *Meekoceras* zone in the basal part of the section. Correlation with Triassic strata in western and central Nevada, southern Idaho, and Utah is based primarily on a similar occurrence of this assemblage. Above the *Meekoceras* zone there are several thousand feet of supposed Triassic sediments which have not been dated exactly. However, conodonts are known to occur above the *Meekoceras* interval and may prove to be of value in correlation. Other fossils are rare and are probably not diagnostic.

Thousands of feet of dense limestone, shaly calcarenite, and shale, all regarded as of Triassic age, are present in the area extending from the Wasatch Mountains of Utah to central Nevada. Evidently the eastern part of the Great Basin was more stable during the Triassic than areas to the north and west where very thick sections occur. However, local high areas in northeastern Nevada during the Triassic are indicated by coarse clastics, present in several sections.

There is evidence to support the existence of a positive element in southeastern Nevada during and after the Triassic period. The absence of Triassic sediments in the area, a Triassic outcrop pattern around the area, and presence of flanking red beds may be explained in this fashion.

Thursday, April 26, 1:45 P.M.
Waldorf Ballroom, Hilton Hotel

GENERAL PALEONTOLOGY AND STRATIGRAPHY

Presiding: R. V. HOLLINGSWORTH, Paleontological Laboratory, Midland, Texas, AND FRANK H. T. RHODES, University of Illinois, Urbana, Illinois

1. THE IDENTIFICATION OF OSTRACODE GENERA AND SPECIES IN THIN SECTIONS

STUART A. LEVINSON
Humble Oil and Refining Co.,
Houston, Texas

Recent research has revealed that a number of Paleozoic ostracode genera and species can be identified in thin section. This is possible because certain shell structures have been found to be constant within ostracode genera and species. Identifications in thin section are based on such characteristics as shell thickness, shell layering and the nature of the individual layers, types of overlap, and the expression in thin section of ridges, frills, spines and sulci.

The results so far attained do not indicate any modification of taxonomic groups; however, there is a suggestion that some closely related species of a few genera, especially *Bairdia*, may be conspecific. The further development of this thin section technique will facilitate the identification of these small fossils in cores and large fragments of well cuttings.

2. A FAUNULE OF UNUSUAL NONMARINE OSTRACODA FROM THE PLIOCENE OF IDAHO

DANIEL J. JONES,* AND NORMAN R. ANDERSON
University of Utah, Salt Lake City, Utah

The fluvio-lacustrine sediments of the Pliocene Idaho formation have yielded a prolific faunule of most unusual ostracodes from a locality 60 miles south of Boise, in Owyhee County, Idaho. Forms represented include highly ornate and spinose species of *Candona*, *Cyprios*, *Limnocythere*, *Ilyocipris*, *Cytherissa*, *Tuberocypris*, *Tuberocyproides*, and *Darwinula*. The faunule occurs in fine-grained siltstones, with abundant gypsum crystals and oolites. The lake(s) in which the ostracodes lived was probably quite shallow, and subject to periodic and significant changes in volume, area, and concentration of dissolved salts. Periodic decreases in the volume of water may have been significant in the development of the bizarre ornamentation of the Ostracoda. Two new genera and several new species are described and illustrated.

* Person presenting paper.

3. CONODONTS FROM THE TYPE CHESTER, ILLINOIS

CARL B. REXROAD
Texas Technological College,
Lubbock, Texas

The presence of conodonts in the rocks of the type Chester area has been known for some time. A study was undertaken to evaluate their use as Chesterian guide fossils in the expectation that they would prove valuable aids in correlations of other strata with the type section.

The shales and thin, interbedded limestones of the complete stratigraphic sequence were carefully sampled. Conodont-producing zones were found in every other formation. These formations are the Renault, Paint Creek, Golconda, Glen Dean, Vienna, Menard, Clore, and Kinkaid.

The fauna consists of 27 identified species be-

longing in nine genera, and three additional genera are known from fragments. The genera present are *Cavusgnathus*, *Cladognathus*, which is a new genus *Gnathodus*, *Hibbardella*, *Hindeodella*, *Ligonodina*, *Ozarkodina*, *Prioniodus*, *Spathognathodus*, *Subbryantodus*, *Synprioniodina*, and *Trichonodella*. Single specimens or groups of fragments represent the polygnathids and two apparently new genera. This fauna is distinct from lower and middle Mississippian assemblages and from the Pennsylvanian. Species will be more useful than genera in subdividing the series. In order further to evaluate conodonts as a tool for stratigraplc analysis of the Chester Series, additional researches on the Glen Dean formation of Kentucky and Indiana as well as of Illinois are in progress.

Conodont faunas similar to those of the type Chester series have been found in the Pella beds of Iowa, the Pitkin limestone of Arkansas and Oklahoma, the lower part of the Stanley shale of Arkansas and Oklahoma, the Barnett formation of Texas, and that portion of the Caney shale studied by Branson and Mehl.

4. UPPER DEVONIAN SUBSTAGES AND THEIR WORLD-WIDE CORRELATION ON THE BASIS OF CONODONTS

KLAUS J. MÜLLER

University of Iowa, Iowa City, Iowa

The Upper Devonian cephalopod limestones of Europe have yielded very rich conodont faunas, from which *Palmatolepis* has been studied extensively, The available representatives of this genus, about 4500 specimens, come from 70 localities, widely distributed over middle and western Europe, and they are from all five of the Upper Devonian stages that have been established on the basis of ammonoids. None of the 27 species present (of which 15 are new) occurs in all these stages, and some have a short vertical range. Since many species are close to or even conspecific with those which are present in North America, they are excellent for long-range correlation.

The conodonts confirm the belief that in the Upper Devonian of this country the correlatives of the *Manticoceras*-Stufe are widespread (e.g., the Genesee, Independence, Amana, Sweetland Creek, and Hackberry shales, as well as parts of the Ohio, New Albany, and Grassy Creek shales). Furthermore, equivalents of the *Cheiloceras*-Stufe and *Platyclymenia*-Stufe are present within the Ohio, New Albany, Grassy Creek, and Maple Mill shales, a correlation that has not been disclosed by ammonoids. Conodonts from equivalents of the *Oxyclymenia*-Stufe and *Wocklumeria*-Stufe are not known from America.

By the recognition of additional morphological features, the taxonomy of Devonian conodonts has been improved. Three subgenera are established, and they have biochronologic significance. An undescribed species of *Palmatolepis* (*Palmatolepis*) has a length of 4.5 mm. and is the largest conodont known to date.

There is now evidence that conodonts were enclosed by a combination of two different types of tissue; one produced the layer-by-layer structure of the conodont, and the other was merely a supporting tissue, which may have secreted another hard part, the "base." The "crimp" a new term, and the growth lamellae are discussed. They are regarded as evidence that there is a considerable change in form and pattern of sculpture within the development of each specimen, as well as a comparably wide range of variability of some features within the species.

Both the regeneration and the healing of broken parts are illustrated.

5. SPECIFIC VARIATIONS AMONG ARENACEOUS SILURIAN FORAMINIFERA FROM ILLINOIS*

HOWARD SCHWALB† AND CHARLES COLLINSON

Illinois State Geological Survey, Urbana, Illinois

Arenaceous foraminifera are very abundant in Silurian strata of the Eastern Interior Basin and have considerable value as stratigraphic markers. Thousands of specimens from the 5-inch Superior Oil Co.-H.C. Ford et al., C.17 well core from White County, Illinois, show much more morphologic variation which is of little taxonomic significance. Among the coiled forms there is variation in the plane of coiling of whorls, deviation from the coiling habit, irregular inflation of the chamber, and duplication or triplication of the chamber. Among straight or curved forms there is difficulty in consistently identifying species due to variations of curvature, rates of expansion, and the lack of preservation of the proloculum. Recognition of these morphologically distinct but taxonomically insignificant variations is important in differentiation of species. The resulting clarification and reevaluation of species should increase the usefulness of these forms as stratigraphic indices.

6. ACANTHOCLADIA GUADALUPENSIS GIRTY, A POSSIBLE ALGALBRYOZOAN SYMBIOT

J. KEITH RIGBY

Brigham Young University, Provo, Utah

The bryozoan, *Acanthocladia guadalupenis* Girty, and the alga, *Solenopora texana* Johnson, consistently occur together in many thin sections of Permian limestone from Texas and New Mexico. *Solenopora* apparently forms the entire minutely cellular reverse side of *Acanthocladia* and consists of small radiating, unchambered but branching, tubules. These tubules ultimately connect at their bases with a "canal" system which surrounds the zooecial wall. This close relationship between bryozoans and algae indicates that the pinnate *Acanthocladia* is probably an algal-bryozoan symbiot.

Cellulose peels prove more useful for detailed

* Published with permission of the Chief, Illinois Geological Survey.

† Person presenting paper.

observation than do thin sections, for the peels show distribution of structure on a nearly plane surface.

7. DENDRASTER: A PROBLEM IN ECHINOID TAXONOMY

D. M. RAUP
Harvard University, Cambridge, Massachusetts

Intraspecific variation in the echinoid genus *Dendraster* is studied by means of a statistical analysis of variation in the living species, *D. excentricus*. The character "eccentricity" is analyzed in samples from thirty-four collections of *D. excentricus*. This character is prominent in current classifications of the genus.

It is found that observed eccentricity data are biased by an allometric relation between eccentricity and test length. This allometry is described by an empirically derived curve. The parabolic function defining this allometric curve is used to eliminate the length bias from the eccentricity data.

No systematic geographic variation is recognized in *D. excentricus* as reflected in the character eccentricity. However, the species may be divided into two ecological races on the basis of eccentricity. The race inhabiting sheltered bays is significantly less eccentric than the race living along the open coast.

The eccentricity data for *D. excentricus* is employed in a review of the classification of the fossil members of the genus. The heretofore unrecognized allometry and ecological variation in *Dendraster* may explain some of the difficulties encountered in the fossil classification. It is found that there are greater differences in eccentricity between populations of *D. excentricus* than there are between species in the fossil record.

ANNUAL BUSINESS MEETING

The annual business session of the Society was called to order at 4:30 P.M., Tuesday, April 24, by Francis J. Pettijohn, president, who introduced the officers for the new year as follows: President, Robert R. Shrock; Vice-President, Richard V. Hollingsworth; Secretary-Treasurer, Samuel P. Ellison, Jr., Editor of the *Journal of Paleontology*, William M. Furnish; and Editor of the *Journal of Sedimentary Petrology*, Jack L. Hough. Pettijohn remains a member of the Council as Past-President.

It was moved, seconded, and carried that the minutes of the 1955 meeting be approved as published in the *Journal of Paleontology*, Volume 29, Number 4 (July, 1955).

The following reports were given.

1. *Report of the 1955 Society's Editors for the Journal of Paleontology* (*A. K. Miller and W. M. Furnish*).—Volume 29 of the *Journal of Paleontology*, issued in conjunction with The Paleontological Society, contains a total of 1084 pages and 108 collotype plates. There are 58 papers plus paleontological notes, nomenclatural notes, reviews, and an author-subject index. Society records, miscellaneous notices, and abstracts of meetings are also included.

This volume represents an increase of 196 pages and 8 collotype plates over the preceding one. It also exceeds a ten-year average by 260 pages and 4 plates. The March, July, and November issues (sponsored by the S.E.P.M.) total 496 pages and 36 collotype plates; representing an increase of 38 pages of text and a decrease of 12 plates from that in corresponding issues of Volume 28. Most manuscripts have been published within nine months after being received; those on hand have maintained the margin.

In the S.E.P.M. issues of Volume 29, there are twenty-seven papers, inclusive of Paleontological Notes. Nine were contributed by authors outside North America. A variety of subjects are treated, but the majority, seventeen, deals primarily with systematic descriptions of fossil or living animals. There are three studies on taxonomy and three on biostratigraphy; one is a bibliography, and three are chiefly concerned with ecology. Emphasis has been placed upon the descriptive and applied aspects of micro-organisms—fourteen of the twenty-seven titles and some 70% of the total text. Papers primarily devoted to descriptions of Foraminifera and Ostracoda constitute nine titles and some 50% of the over-all text as well as two-thirds of the plates. Studies are about evenly divided between Paleozoic and post-Paleozoic. Eight reviews of current literature and three nomenclatural notes were published.

Miller relinquished duties as co-editor on January 1, 1956. Furnish assumed full responsibility at that time and also attended The Paleontological Society council meeting in New Orleans as official representative of the S.E.P.M. The State University of Iowa contributed financial assistance in the form

of miscellaneous supplies and expenses.

2. *Report of the Editor of the Journal of Sedimentary Petrology* (*Jack L. Hough*).—The *Journal of Sedimentary Petrology* was published in 1955 under the direction of Acting Editor Ralph E. Grim, as volume 25, numbers 1 through 4. Each number contained 80 pages. Seventeen hundred copies of the first three issues were printed, and nineteen hundred copies of the fourth issue were printed. The contents of the volume included 32 technical articles, one note, two discussions, two reviews, 3¼ pages of announcements, abstracts of papers given at the 1955 S.E.P.M. meeting in New York, and an index. Three and a half pages of advertisements of Society publications were run. The distribution of articles, notes, and discussions according to national origin was as follows: United States, 33; Italy, 1; and Japan, 1.

The backlog of manuscripts has increased, during the latter part of the year, to a size which makes a further expansion of the *Journal* highly desirable. As may be seen in the report of the Secretary-Treasurer, the net income of the *Journal* was over $1200.00.

As in the past six years, the University of Illinois has provided a half-time editorial assistant.

J. L. Hough, Editor, returned to his regular duties at the University of Illinois in September, after 18 months absence on an assignment as Head of the Department of Geology and Geophysics, Indian Institute of Technology, Kharagpur, India. Responsibility for acceptance of manuscripts and other matters in the later part of 1955 and early 1956 is divided between Acting Editor Grim and Editor Hough.

3. *Report of the Secretary-Treasurer* (Samuel P. Ellison, Jr.).—

BACK VOLUME SALES

(January 1, 1955, to December 31, 1955)

Journal of Paleontology, Volumes 1–29	$4,265.56
Journal of Sedimentary Petrology, Volumes 1–25	850.32

SPECIAL PUBLICATION SALES

(January 1, 1955, to December 31, 1955)

Turbidity Currents	$ 210.75
Recent Marine Sediments	$3,607.00
Finding Ancient Shorelines	$2,958.45

PRINTING AND ENGRAVING BILLS FOR 1955

Journal of Paleontology

	Banta Printing Bills		*Meriden Engraving Bills*	*Total Printing and Engraving Bills*	*S.E.P.M. Total Printing and Engraving Bills*
	Printing	*Postage*			
Number 1 (Jan.)*	$ 2,991.74	$ 93.15	$1,090.82	$ 4,175.71	
Number 2 (Mar.)	2,319.14	55.25	234.37	2,608.76	$2,608.76
Number 3 (May)*	3,551.72	109.24	1,156.37	4,817.33	
Number 4 (July)	3,199.83	91.62	467.33	3,758.78	3,758.78
Number 5 (Sept.)*	2,672.24	93.82	885.28	3,651.34	
Number 6 (Nov.)	2,484.01	81.76	867.93	3,433.70	3,433.70
	$17,218.68	$524.84	$4,702.10	$22,445.62	$9,801.24
1954 Totals	$14,771.40	$447.17	$4,183.75	$19,402.32	$9,714.11

* Odd numbers paid by Paleontological Society.

Journal of Sedimentary Petrology

	Banta Printing Bills		
	Printing	*Postage*	*Total*
Number 1 (March)	$1,274.93	$ 66.73	$1,341.66
Number 2 (June)	1,174.85	85.14	1,259.99
Number 3 (September)	1,222.39	85.58	1,307.97
Number 4 (December)	1,364.91	91.13	1,456.04
	$5,037.08	$328.58	$5,365.66
(1954 Totals)	$4,707.49	$268.37	$4,975.86

MEMBERSHIP, MAILING, AND JOURNAL STATISTICS

	Dec. 31, 1955	Dec. 31, 1954	Dec. 31, 1953
1. S.E.P.M. Membership:			
Active Members	895	751	635
Associates	285	310	305
Correspondents	5	5	5
Honorary Members	3	1	1
TOTAL	1,188	1,067	946
2. *Journal of Paleontology* Mailing List:			
S.E.P.M. Active & Honorary Members	485	434	383
S.E.P.M. Associates	155	165	177
Subscribers	722	684	692
P.S. Members	610	612	566
TOTAL	1,972	1,895	1,818
3. *Journal of Sedimentary Petrology* Mailing List:			
S.E.P.M. Active & Honorary Members	607	483	402
S.E.P.M. Associates	171	183	186
S.E.P.M. Correspondents	5	5	5
Subscribers	806	740	671
TOTAL	1,584	1,411	1,264
4. Edition, *Journal of Paleontology*	2,200	2,200	2,100
5. Edition, *Journal of Sedimentary Petrology*	1,800*	1,700	1,400
6. Number of Pages, *Journal of Paleontology*	1,084	888	910
7. Number of Plates, *Journal of Paleontology*	108	100	91
8. Number of Pages, *Journal of Sedimentary Petrology*	317	298	301
9. New Members	161	133	76
10. Transfers to Active Membership	47	44	2
11. Members and associates dropped for non-payment of dues	16	28	37

* 1,900 copies beginning with December, 1955.

FINANCIAL STATEMENT FOR THE YEAR ENDED DECEMBER 31, 1955

CERTIFICATE OF INDEPENDENT PUBLIC ACCOUNTANTS

The Council, Society of Economic Paleontologists and Mineralogists:

We have examined the balance sheet of Society of Economic Paleontologists and Mineralogists at December 31, 1955 and the related statement of income and surplus for the year then ended. Our examination was made in accordance with generally accepted auditing standards, and accordingly included such tests of the accounting records and such other auditing procedures as we considered necessary in the circumstances.

In our opinion, the accompanying balance sheet and statement of income and surplus present fairly the financial position of Society of Economic Paleontologists and Mineralogists at December 31, 1955 and the results of its operations for the year then ended, in conformity with generally accepted accounting principles applied on a basis consistent with that of the preceding year.

ARTHUR YOUNG & COMPANY

Tulsa, Oklahoma, January 13, 1956

SOCIETY OF ECONOMIC PALEONTOLOGISTS AND MINERALOGISTS
BALANCE SHEET, DECEMBER 31, 1955

ASSETS	Total	General Fund	Publication Fund
CURRENT ASSETS:			
Cash	$23,462.14	$19,188.37	$4,273.77
Savings account	2,608.48	2,608.48	—
Accounts receivable	96.25	93.50	2.75
Total current assets	$26,166.87	$21,890.35	$4,276.52

PUBLICATIONS:			
Journal of Paleontology:			
Issues prior to 1955—14,066 journals at 50¢ each (2,233 complete volumes)	$ 7,033.00	$ 7,033.00	$ —
Issues 1 to 6 of 1955—1,212 journals, at cost	2,144.93	2,144.93	—
Reprints in 1948, Volume 1, 1927—729 volumes, at cost	1,592.19	1,592.19	—
Journal of Sedimentary Petrology:			
Issues prior to 1955—2,371 journals at 50¢ each (690 complete volumes)	1,185.50	1,185.50	—
Issues 1 to 4 of 1955—634 journals, at cost	504.52	504.52	—
Special publications:			
Turbidity Currents, 496 issues, at cost	424.13	—	424.13
Recent Marine Sediments, 1,175 issues, at cost	2,424.61	—	2,424.61
Total publications	$15,308.88	$12,460.14	$2,848.74
FURNITURE AND FIXTURES (less reserve, $1,769.26)	$ 1.00	$ 1.00	$ —
DEFERRED CHARGES	$ 1,077.74	$ 100.84	$ 976.90
	$42,554.49	$34,452.33	$8,102.16
LIABILITIES AND SURPLUS			
CURRENT LIABILITIES:			
Accounts payable	$ 2,575.37	$ 2,575.37	$ —
Amount payable to Paleontological Society	2,805.86	2,805.86	—
Accrued printer's charges	2,287.78	1,400.00	887.78
Total current liabilities	$ 7,669.01	$ 6,781.23	$ 887.78
DEFERRED CREDITS:			
Subscriptions to journals—net of portion to be received by Paleontological Society	$ 6,417.68	$ 6,417.68	$ —
Subscriptions to special publications	2,958.45	—	2,958.45
Membership dues for 1956 and 1957	7,380.80	7,380.80	—
Total deferred credits	$16,756.93	$13,798.48	$2,958.45
SURPLUS PER ACCOMPANYING STATEMENT	$18,128.55	$13,872.62	$4,255.93
	$42,554.49	$34,452.33	$8,102.16

(*See also page 1016*)

4. *Report of the Research Committee (Raymond Siever, Chairman).*—The members of this committee, as of April, 1955, were O. L. Bandy, W. C. Bell, B. Kummel, H. A. Lowenstam, E. D. McKee, R. H. Nanz, F. J. Pettijohn, W. J. Plumley, R. Siever, L. L. Sloss, H. E. Summerford, C. Teichert, F. B. Van Houten, and L. E. Workman.

At the annual meeting of the committee in 1955, the topic, "Directional Properties of Sedimentary Rocks," was selected for the symposium to be presented at the 1956 meeting. The general principles governing the choice of papers were that a fairly broad coverage of the topic be insured and that presentations should be of new material. Speakers invited were E. D. McKee, G. Rusnak, J. R. Curray, L. C. Bonham, J. E. Sanders, and A. Carozzi. Subjects discussed were experimental production of crossbedding, relation of grain shape fabrics to crossbedding, grain shape fabrics of modern sediments, turbidity current directional structures, and studies of various directional properties in some California sediments and in the sediments of an Alpine basin. This symposium may be published as a special volume.

This year the Research Committee selected two outstanding papers in the *Journal*

(*Continued on page 1017*)

SOCIETY OF ECONOMIC PALEONTOLOGISTS AND MINERALOGISTS
STATEMENT OF INCOME AND SURPLUS
YEAR ENDED DECEMBER 31, 1955

	Total	*General Fund*	*Publication Fund*
INCOME:			
Membership dues and subscriptions:			
Journals of Paleontology and *Sedimentary Petrology*	$ 3,920.00	$ 3,920.00	$ —
Journal of Paleontology	12,946.03	12,946.03	—
Journal of Sedimentary Petrology	6,889.76	6,889.76	—
	$23,755.79	$23,755.79	—
Sales of special publications:			
Turbidity Currents	$ 210.75	$ —	$ 210.75
Recent Marine Sediments	3,607.00	—	3,607.00
	$ 3,817.75	$ —	$ 3,817.75
Sales of back numbers:			
Journal of Paleontology, Volumes 1 to 29	$ 4,265.56	$ 4,265.56	—
Journal of Sedimentary Petrology	850.32	850.32	—
	$ 5,115.88	$ 5,115.88	—
Sales of plates	$ 462.97	$ 462.97	$ —
Advertising	$ 532.82	$ 532.82	$ —
Donations ($4,683.64 from The American Association of Petroleum Geologists)	$ 5,567.92	$ 4,683.64	$ 884.28
Miscellaneous	$ 265.17	$ 265.17	$ —
	$39,518.30	$34,816.27	$ 4,702.03
Less: Proportion of 1955 income accrued to Paleontological Society	2,404.45	2,404.45	—
COSTS AND EXPENSES:			
Cost of printing:			
Journal of Paleontology	$10,546.00	$10,546.00	—
Journal of Sedimentary Petrology	4,977.03	4,977.03	—
Recent Marine Sediments	4,166.29	—	$ 4,166.29
	$19,689.32	$15,523.03	$ 4,166.29
Expenses:			
Clerical salaries	$ 6,129.74	$ 6,129.74	$ —
Office supplies	459.70	459.70	—
Postage and express	1,461.81	1,197.58	264.23
Office rent	1,500.00	1,500.00	—
Telephone	113.45	113.45	—
Audit fee	200.00	200.00	—
Payroll taxes	171.61	171.61	—
Convention expense	283.92	283.92	—
Miscellaneous	754.14	636.00	$ 118.14
	$11,074.37	$10,692.00	$ 382.37
Adjustment for (increase) decrease in inventory of publications	$(1,514.94)	$ 834.42	$(2,349.36)
	$29,248.75	$27,049.45	$ 2,199.30
NET INCOME	$ 7,865.10	$ 5,362.37	$ 2,502.73
SURPLUS AT DECEMBER 31, 1954	10,263.45	8,510.25	1,753.20
SURPLUS AT DECEMBER 31, 1955	$18,128.55	$13,872.62	$ 4,255.93

of Sedimentary Petrology and the *Journal of Paleontology* for best paper awards. The award for the best paper in the *Journal of Sedimentary Petrology* for the year 1954 was given to "Sedimentary Framework of the Modern Mississippi Delta" by H. N. Fisk, E. McFarlan, Jr., C. R. Kolb, and L. J. Wilbert, Jr. (deceased). The award for the best paper in the *Journal of Paleontology* for the year 1954 went to "Quantitative Studies of Brachiopods from the Lower Carboniferous Reef Limestones of England" by Donald Parkinson. These awards were presented at the joint session of the A.A.P.G.-S.E.P.M. by Raymond Siever, Chairman of the Committee.

The Research Committee presented to the Council by unanimous vote the nomination of Raymond C. Moore as an Honorary Member of the Society. The Council approved and the presentation was made at the joint annual meeting by J. M. Weller.

The committee has sought means to stimulate research in addition to the arranging of symposia at annual meetings. As an experiment, the chairman and others in the North-central states organized a small, regional, informal one-day meeting with the purpose of bringing together active research workers to exchange ideas and discuss research problems in an informal conference atmosphere. It is hoped that in the next year similar meetings will be organized by members of the committee in various parts of the country. These meetings may pave the way for having more-or-less regular meetings of research groups in various parts of the country with fluid programming in which there can be a free interchange of ideas.

At the close of the 1956 meeting Curt Teichert took over the duties as Chairman of the Committee.

5. *Report on the Earth Sciences Division of the National Research Council (F. J. Pettijohn, S.E.P.M. Representative).*—The program of the Division of greatest interest to members of S.E.P.M. probably is that of the various Division committees, especially the Advisory Committees for screening candidates for National Science Foundation Fellowships—both predoctoral and postdoctoral. The technical committees whose activities are of greatest interest to sedimentologists and paleontologists include the Committee on Clay Minerals, the Committee on Stratigraphy and the Committee on the Treatise on Marine Ecology and Paleoecology. The Committee on Clay Minerals has sponsored a series of annual conferences on clay mineralogy, the proceedings of which are edited by members of the committee and published and distributed by the National Research Council. Both the Committee on Stratigraphy and the Committee on the Treatise have about completed their assignments. The former has issued a series of reports and correlation charts over the years which are familiar to all stratigraphers. The latter committee has completed its work on the *Treatise* which should soon be available for distribution. The Committee on Review Articles in Geology and Geophysics has been transferred to the Geological Society of America. The Committee on the Chemical Composition of Sediments has been discharged.

6. *Report on the American Geological Institute (F. J. Pettijohn).*—The By-Laws of S.E.P.M., as now revised, specify that the president and past-president shall be the Society representatives on the Board of Directors of the American Geological Institute. Your present representatives, therefore, are Hans E. Thalmann and myself. Dr. Thalmann is unable to be present at this meeting so the responsibility of reporting to you on the activities of A.G.I. is mine. Unfortunately, as I did not go to New Orleans and could not attend the Directors meeting my report is a second hand account.

The principal item to report, perhaps, is the greatly expanded circulation of the A.G.I. *Newsletter*. This publication is now sent without charge to all the members of all the affiliated societies. As a result, everyone is now conversant with the activities of the Institute, its plans and problems. Hence an extended report by me would be put a repetition of what readers of the *Newsletter* already know. The Institute is now able to report directly to its constituents.

The S.E.P.M. participates in Institute activities in several ways. In addition to the two directors mentioned above, it is represented on the Glossary Committee and on the Government Relations Committee. Willard Pye was our representative on the Glossary Committee. At his request he has

been replaced by Jules Braunstein who, with assistance of several others, has completed compilation of the terms and definitions pertaining to sedimentology and sedimentation. Norman Hinchey has recently been appointed our representative on the Government Relations Committee.

For reasons pointed out above, it seems unnecessary to render a detailed summary of Institute activities and accomplishments. But deserving of emphasis, even at the risk of repetition, is the problem of financing the Institute. Despite much thought and labor on this knotty problem, no adequate solution has been found. From its inception the A.G.I. has been financed on a shoestring and it has operated on a deficit budget since 1950–51. It is obvious that this state of affairs cannot long continue. Clearly the member societies, of which S.E.P.M. is one, who joined with the National Academy of Sciences and the National Research Council to form the Institute, must face up to the problem of providing adequate funds. If they are not willing to do so, the Institute faces bankruptcy.

It seems to your representative that we shall soon have to decide whether we really want a profession-wide organization devoted to geologists and their problems. Perhaps the issues have been confused and A.G.I. has been regarded as another geological society or an inter-society committee. Actually it is neither; its aims and objectives are professional rather than scientific. Its concern is geologists, not geology. Do geologists need an organization, comparable to the American Medical Association or the American Bar Association, concerned with professional ethics, employment of geologists, education and recruitment of geology students, licensing of geolcgists, public relations, the utilization of geologists in government and military affairs, and the like? If we do, we shall have to pay for it.

7. *Report of the Joint Committee on Invertebrate Paleontology* (*Raymond C. Moore*). —The Joint Committee on Invertebrate Paleontology is composed of 30 members chosen from the Society of Economic Paleontologists and Mineralogists, the Paleontological Society, and the Paleontographical Society for the purpose of guiding accomplishment of the project to publish a comprehensive, highly authoritative *Treatise on Invertebrate Paleontology*. Seventeen S.E.P.M. members (*Branson, Dunbar, *Frizzell, *Howe, *Howell, *Knight, Lalicker, *Miller, *Moore, *Newell, Reeside, Rolshausen, Shrock, *Stenzel, Swartz, Warthin, *Weller) belong to this committee and in addition the Society is represented by 41 contributing authors (10 from the preceding list marked by an asterisk and Barker, Bassler, Bell, Boardman, Durham, Furnish, Gardner, Glaessner, Hanna, Hatai, Hessland, King, Kummel, Levinson. Loeblich, Lowenstamm, Olsson, Palmer, Peck, Puri, Scott, Shaver, Sohn, Stainbrook, Stephenson, Swain, Tasch, Teichert, Thompson, Ubaghs, Youngquist). These, as well as all other authors and the Editor, receive no financial remuneration of any kind. The Geological Society of America has made grants for the *Treatise* project amounting to $35,000 and has aided some individual authors by grants totalling at least $5150; also, this Society is handling costs of publication and distribution on a basis of minimum possible charge for unit volumes as they are issued. Thus, taken all together, this is a collaborative undertaking of unparalleled magnitude.

A survey of the project as of April, 1956, comprising an inventory of both published and unpublished materials, indicates that the work of organizing the *Treatise* is approximately 60 percent accomplished, although only 5 of the 22 planned parts actually are published and available for use. These are Parts D (radiolarians, tintinnines), E (archaeocyathids, sponges), G (bryozoans), P (chelicerates, pycnogonids), and V (graptolites), which aggregate 928 pages with approximately 5415 individual figures. Each volume is priced at $3.00 (except P, at $3.50), with mailing cost included, and all orders are being handled by the Geological Society of America headquarters at 419 West 117th Street, New York 27, N. Y. Two parts which are now in press are F (coelenterates) and L (ammonoids); these will contain a total of nearly 1000 pages with approximately 6800 individual figures. Expected to be made ready for press during the first half of 1956 were Parts C (foraminifers), O (trilobites), and Q (ostracodes), but delays of some authors in

finishing their assignments indicate necessary postponement of publication. Several other units, however, are moving ahead about as well as can be expected and a few unhappily, at snail's place. The limiting factors in issuing volumes of the *Treatise* are the speed at which contributing authors are able and willing to finish their assignments, time available for editorial work (the editor has given nearly full time in many recent months), and capacity of the University of Kansas Press which has handled all setting of type and organization of published pages. Ultimately, the task will be finished, if not by the present Editor and those working with him, by others, for the status of the *Treatise* as an indispensible foundation for future studies in invertebrate paleontology is assured. Along with a statement of the present aim of carrying the project ahead as steadily as possible, a realistic forecast must point out that years, rather than months, will elapse before the last planned volume is issued.

Special mention should be made of assistance which has been furnished during 1954–56 by H. J. Harrington in advancing the volume on trilobites and during 1955–56 by P. C. Sylvester-Bradley in organizing the volume on ostracodes. Work by these men has been done while carrying on other tasks as visiting professors at the University of Kansas.

In summary, accomplishments are now appreciable and output of additional volumes of the *Treatise* at a reasonable rate seems to be assured. Progress mainly depends on the continued support of authors who are working together and of the Societies which jointly have underwritten the project.

Finally, it seems appropriate to report that several authors (at least 17), who have made no appreciable progress on their accepted commitments in the past 5 years, now seek to extend time for accomplishing their *Treatise* work to 1960 or even 1964, otherwise withdrawing from the project, and to record the fact also that critical review of received contributions generally has led to complete rewriting (for some texts 3 times), thus retarding completion of readiness for press. On some typescripts the Editor has spent as much or more time probably than that used by the author, leading to innumerable corrections of mainly nomenclatural nature. This entails extended correspondence but at length satisfactory conclusions are reached. Then the segment of *Treatise* material is approved for publication. In this connection, paleontologists generally may be interested in part of a letter sent to the Editor by one of the *Treatise* authors whose contribution has been or is being currently published: "Please accept my sincerest thanks for the trouble you took on my account in correcting numerous nomenclatural errors which would otherwise have lowered the value of my work. As it now is, I firmly believe that it (my *Treatise* chapter) will be a credit to us both, to me as author and to you as editor. And I wish to add in all sincerity how deeply I feel my obligation to you, a feeling which has not lost but considerably gained through our sometimes sharp disagreements in the course of preparing the manuscript. In one of your letters you remarked that you have made enemies as editor. Please do not count me as one of them but consider me as one of your friends." Such communications help to pay for behind-the-scenes labor in producing the *Treatise*.

8. *Report of the Advisory Committee on Radioactive Mineral Exploration (H. N. Fisk)*.—Two meetings of the Advisory Committee on Radioactive Mineral Exploration were held since the 1955 Business Meeting of the S.E.P.M. Frederick H. Lahee was re-elected chairman and Cecil H. Green was elected vice-chairman at the first of these meetings which was held in Houston, Texas, on May 17, 1955. The types of radioactive detection instruments now being manufactured for sale was the main topic of discussion.

The status of cooperation between the Committee and the Atomic Energy Commission was reviewed at the second meeting held on October 28, 1955, in Dallas, Texas. It was reported that 476,000 feet of seismic shotholes had been logged in the Rocky Mountain Region by May, 10, 1955; of this total, 106,000 feet were logged by the oil companies using the Atomic Energy Commission's equipment, and 370,000 feet were logged by A.E.C. personnel with permission of the various companies. Information con-

cerning the utilization of logs of seismic shotholes for radioactive exploration in other regions is not available. Also discussed were the advantages and disadvantages of probing holes as contrasted with examination of cuttings brought up in the drilling of these holes.

9. *Report of the Representative on the Committee for the Glossary of Geologic terms, (Jules Braunstein).*—The present S.E.P.M. representative on the Glossary Project was appointed shortly after the first of 1956, following the resignation of the previous representative. Therefore, no meetings of the Committee have been attended, and no first hand report of the progress of the project can be made.

Several lots of definitions were received in January, which were the results of work by the former representative, as well as material compiled at the University of Iowa. All of these were checked for acceptability of usage, and citation of authorship, and many were rewritten. In this work, the writer was assisted by Robey Clarke, Roger Corbeille, and McLain Forman, all of New Orleans. The final group of new and/or revised definitions was sent to the Chairman of the Glossary Project in mid-February.

A number of definitions which should have been included in the S.E.P.M. portion of the Glossary may have been overlooked due to the shortness of time available between the appointment of the new representative and the stated deadline for submission of material. It is therefore recommended that the S.E.P.M. maintain a permanent Glossary Committee that will be responsible for compiling corrections and additions to the Glossary for publication as annual or biennial supplements.

10. *Report of Pacific Coast Section (W. H. Easton).*—The Pacific Section now has 250 members, most of whom are employed in southern California. The balance in the treasury is $1698.40, as reported by R. L. Pierce, Secretary-Treasurer.

The monthly Biostratigraphy Seminar, which is sponsored jointly by the S.E.P.M. and Bakersfield Evening School, is being continued this year with eight meetings on the program.

On February 19 the Pacific Section sponsored a one-day field trip to the type area of the Tejon formation (Eocene) in Live Oak Canyon. About 140 geologists attended. Leaders were S. Carlson and J. Bigelow. This was the first opportunity for general access to this important section in eleven years, inasmuch as it is on closed land.

On May 4 and 5 the Pacific Section will sponsor a field trip to the Huasna area near Santa Maria. The leader will be F. D. Crawford. Preliminary papers will follow a get-together and barbecue on May 4 in Santa Maria. This will be the first time that a field trip will have been arranged for the Santa Maria District. Important Miocene successions and complicated structures are exposed.

The Pacific Section will again cooperate with A.A.P.G. and S.E.G. at the Pacific Section Annual Meeting in Los Angeles on November 8 and 9. The annual dinner of the Pacific Section will be on November 8. A half-day technical session will be on November 9.

As usual, S.E.P.M. A.A.P.G., and S.E.G. sponsored a dinner dance near Christmas, the date being December 3 this year.

11. *Report of Gulf Coast Section (E. H. Rainwater).*—The Section is now in its third year, and has a membership of approximately 220, located in various parts of the Gulf Coastal plain. The aim of the Section, as set forth in the Constitution, is "to promote the science of stratigraphy in the Gulf Coast states through research in paleontology and sedimentary petrology." Membership is restricted to persons who are members or associate members of S.E.P.M.; associate members are those persons who otherwise qualify for membership but who are not members or associate members of S.E.P.M.

Membership dues are $1.00 per year. This income from dues is used to pay the cost of printing and mailing notices, newsletters, membership cards, and publications by the Section.

A constitution for the Section was adopted in 1954 and it provides, among other things, for:

1. An annual meeting, which "will usually be held in conjunction with the annual meeting of the Gulf Coast Association of Geological Societies." Our 1954 and 1955 business meetings were held during the annual meetings of the G.C.A.G.S.

2. An editor, appointed by the president, who "shall actively solicit papers from the Section membership for presentation at the annual meeting." Our editor already has commitments for three papers by members of the Section for presentation at the 1956 annual meeting of the G.C.A.G.S. in San Antonio, October 31–November 2, and for publication in the *Transactions*. The Gulf Coast Section of S.E.P.M. participated in the technical program of the 1954 and 1955 annual meetings of the G.C.A.G.S.

3. Business Representatives, appointed by the president, one from each local geological society affiliated with the Gulf Coast Association of Geological Societies. At present we have a business representative in each of the 12 local geological societies in the Gulf Coast who are actively engaged in soliciting papers for the annual meeting, recruiting new members for the Section, and keeping our members in the area represented informed of the activities and plans of the Section.

It is clear that the founders of the Section intended that it cooperate closely with the G.C.A.G.S. **This** could **not** be otherwise, as the Section's members are also members of the G.C.A.G.S. However, the organization and the objectives of the two societies are distinct, and it is possible that the Gulf Coast Section of S.E.P.M. will sometimes wish to hold its own session at the Annual Meeting. Also, the Section has underway some projects which are of special interest to its members. These are:

1. Improvement of well samples. A report on "Technique of Catching and Handling Well Samples," Special Publication No. 1 of the Section, was published in the *Oil and Gas Journal* and *World Oil*, and copies were sent to 280 companies who operate in the Gulf Coast. This report was written primarily from the viewpoint of micropaleontologists who work in the Gulf Coast Oligocene and Miocene belts. An expanded report, to include a description of the proper methods for obtaining samples in upper Gulf Coast wells, primarily for lithology and paleoecology, is now being prepared.

An objective of the Section, though not an active project, is to interest the state geological surveys in preserving a "master set" of cuttings and core samples from key wells.

2. The major project of the Section is the compilation of data on the type localities and type subsurface sections of all Mesozoic and Cenozoic stratigraphic units in the Gulf Coast. A list of over 300 such units has been prepared, and distributed to the membership. Many stratigraphers and paleontologists are now working on this project. It is our plan to publish the information on the type sections. A book of more than 300 pages will be required to include the data which we hope to assemble.

Field Trips

The Gulf Coast Section has arranged for two field trips to be conducted for its members during 1956—one to the classic Miocene localities in western Florida, May 3–5, and the other to Lower Cretaceous exposures in the San Antonio, Texas, area in early November.

General Objectives of the Section

The Gulf Coast Section is getting started at a time when there is renewed interest in paleontology and mineralogy, and it is hoped that the organization can help the stratigraphers, paleontologists, sedimentologists, palynologists ecologists, mineralogists, and petrologists gain proper recognition for their work. These scientists, whether in commercial work, with state or federal surveys, or in the academic field, have had little encouragement to carry on their studies in these basic earth science fields. The managers of the many oil and gas companies operating in the Gulf Coast have for many years considered that electric logs of wells and geophysical surveys of the areas of interest gave most of the information needed in exploring for oil and gas. One of the aims of the Section is to stress the importance of studying the rocks and the fossils, to help improve the conditions of the geologists engaged in this work, and to encourage young geologists to choose one of these branches of geology.

The long-range objective of the Gulf Coast Section is to gain an understanding of the detailed geological history of all parts of the Gulf Coastal plain. Many of the Section's members are making special studies of the sediments and fossils of the Gulf Coast, and will probably publish the results. Others

are active in many ways in carrying out the objectives of the Section.

12. *Report of the Permian Basin Section (Harold L. Williams).*—The Permian Basin Section of the S.E.P.M. sponsored a successful field trip, adopted a constitution, established two local sections that are very active, and conducted a successful membership drive in conjunction with the election of officers for the coming year. Financially, the Section started the year in debt; it ended the year with a modest balance in the bank.

Last October 21 and 22, the P.B.S. sponsored a field trip into the Guadalupe, Brokeoff, and Delaware Mountains of Texas and New Mexico. Under the leadership of Phillip B. King, Norman D. Newell and Donald W. Boyd, 250 geologists reviewed in the field some of the problems and aspects of the Guadalupe and Leonard sedimentation and stratigraphy of the basin, rim and shelf provinces of these Mountains. This successful field trip was the result of a great deal of work by a very small group of men who had a comparatively short period of time at their disposal. They were hampered not only by lack of time but by extremely hard rains in the Mountains which finally necessitated the rebuilding of some roads and the use of National Guard trucks to convey the party over some three miles of mountain roads that were impassable to the average vehicle. The burden of this work was carried by Walter C. Warren, Frank Dameron, Hugh N. Frenzel, Frederick L. Stead, and Walter W. Roye. They were assisted by M. R. Stipp, J. P. D. Hull, Jr., C. D. DiGiambattista, J. M. Alcorn, Don Caussey, Walter R. Berger, Jr., Clyde E. Harrison, Roy F. Milks, G. L. Wilde, and G. T. Schmitt. The P.B.S. is in debt to these 14 men for organizing this most successful field trip that was attended by many famous students of the Upper Permian.

The Constitution Committee, under Berte H. Haigh's chairmanship, wrote a constitution that was unanimously adopted by the Executive Council.

P.B.S. members in Fort Worth and Lubbock organized local sections that hold regular meetings. The Fort Worth group is single-handedly organizing the P.B.S. Annual Meeting to be held May 11 and 12. May 11 is to be devoted to papers and business meetings; May 12 is to be given to a one-day, one-stop, field trip that should be unique in this day of field trips that cover scores of miles. The entire day will be spent studying the geology of one small complex area.

At present the P.B.S. has 354 members, approximately the same as last year, and again one-half reside in Midland.

13. *Report on the Status of the Index to the First Twenty-five Volumes of the Journal of Paleontology (Hans E. Thalmann).*—The card indexing of the first twenty-five volumes of our *Journal* has been terminated, thanks to the efficient and unselfish efforts of the following volunteers, to all of whom the Society of Economic Paleontologists and Mineralogists is deeply indebted: Wolf Maync (Paris), Ralph L. Langenheim (Berkeley), Louise Jordan (Norman), Doris Malkin (Norman), Myra Keen (Stanford), Augusta H. Kemp (Seymour), and I. B. Gold (Los Angeles). Thousands of 3″×5″ cards are at present alphabetically sorted and bundled at Stanford to be used as a manuscript for the printer. This card-manuscript will be delivered, upon completion in the course of this year, to the Headquarters of the Society. The Index will contain all described and figured general, species, and subspecies (or varieties) published in the twenty-five volumes (1927 to 1951) of the *Journal* giving volume, page, plate, figure, age, and locality for each entry and including also taxonomic categories above the genus-level. It is thus intended to result in a reference catalogue rather than becoming an ordinary general index.

14. *Report on Carbonate Rocks Symposium (R. J. LeBlanc).*—A symposium on "Regional Aspects of Carbonate Deposition" was held in connection with the 1954 S.E.P.M. convention in St. Louis and the following papers were formally presented:

"The Distribution of Marine Carbonate Sediments"—JOHN RODGERS
"Calcium Carbonate Deposits of the Great Bahama Bank, British West Indies"—NORMAN D. NEWELL AND J. KEITH RIGBY
"Early Diagenesis and Lithification of Carbonate Sediments in South Florida"—ROBERT N. GINSBURG
"Mississippian Carbonate Deposits of the Ozark Region"—RAYMOND C. MOORE.

Manuscripts of the four papers listed above were submitted to the writer in 1954 and 1955, and plans to publish these papers

together with a complete record of the panel discussion (which includes contributions from L. V. Illing and R. W. Fairbridge) were submitted to the S.E.P.M. Council in the fall of 1955.

In October, 1955, the symposium material was submitted to the George Banta Company, Inc., for an estimate of printing the symposium in a special volume. According to the George Banta Company, Inc. the various manuscripts indicate a book of approximately 192 pages, including numerous illustrations. The cost for publication of this special volume would be approximately $3292 for 1000 copies and $3985 for 2000 copies. On the basis of this cost information, Mr. R. H. Dott, Business Manager, has estimated that the recommended selling price to members would be $5.00 if only 1000 copies are printed and sold, and $3.50 if 2000 copies are printed and sold. This information was submitted to the S.E.P.M. Council, and on October 28, 1955, the writer received approval to proceed with publication of the symposium material as a special publication of the S.E.P.M.

Early in 1956, the various authors were notified that their material was in the process of being edited and would appear as soon as possible as a special volume. This editing job is now approximately half completed and the writer hopes to have it in final form and submitted to the printers in approximately 60 days.

15. *S.E.P.M. President's Report* (*Francis J. Pettijohn*).—The finances of our Society are in good shape and we ended the fiscal year with a surplus. This was accomplished by a raise in dues and by a more equitable sharing of expenses with the Paleontological Society in the publication of the *Journal of Paleontology*. Our bettered finances are the fruit of the labors of a previous administration and of the Russell Committee to whom we are indeed grateful.

The past year saw the reprinting of *Recent Marine Sediments*. This publication, originally sponsored by the American Association of Petroleum Geologists, has been turned over to our Society for reprinting and distribution. *Finding Ancient Shorelines*, a symposium given in Houston in 1953, was also printed and released as a Special Publication. Scheduled for early appearance is the symposium on carbonate deposits presented in St. Louis in 1954. Much to be regretted is the delay between presentation of the papers and their release as a special publication. This lag, discouraging to contributors and editor alike, is due primarily to shortage of funds. Our Publication Fund has been earmarked too far in advance and is replenished so slowly by sales that publication of new material is far too long delayed. During the past year the Publication Fund was augmented by a gift of $884.28 from the New York Oil Finders Convention Committee, which was our pro-rata share of the surplus remaining from the 1955 joint annual meeting in New York. This gift is a most welcome addition to our Publication Fund.

Our membership continues to grow, a ten per cent increase being recorded during the past calendar year. Although this is a reasonable increase, our membership is still much below what it should be to support our program of activities. Forty papers were presented on the S.E.P.M. program in New York; 62 papers were presented on the A.A.P.G. program. Yet S.E.P.M. has less than one tenth the membership of the A.A.P.G.! And many who participate in our programs and read our journals are not members of our Society. Clearly there is a job for an energetic membership committee!

It is with regret that we accepted the resignation of A. K. Miller as co-editor of the *Journal of Paleontology*. As our journals are perhaps our most important undertaking, the editors are therefore our most important officers. We are indeed grateful to Dr. Miller for his efforts in our behalf. We are pleased that co-editor W. M. Furnish will carry the editorial responsibilities for the remainder of this year. Unfortunately for our Society, Dr. Furnish would like to be relieved of his duties at the end of his term. J. L. Hough has returned to active duty as editor of the *Journal of Sedimentary Petrology* after a two years, absence from the country. We are pleased to have him back and are grateful to R. E. Grim for serving as Acting Editor during Dr. Hough's absence.

It appears to some of us that our method of selecting our presidents is not wholly satisfactory. By recent amendments to our constitution and by-laws, only those who

have previously served the Society as editor, secretary-treasurer, vice-president or as chairman of the Research Committee are eligible for nomination for president. This restriction has the merit of giving us candidates with previous contact with Society affairs, which makes for a more effective and efficient discharge of the presidential duties. Unfortunately, our pool of candidates is not very large and tends to shrink. The editorships, and commonly the positions of secretary-treasurer and chairman of the Research Committee do not rotate, so that in many years only one new name is added to the roster of those eligible for the presidential nomination. As two are nominated each year and only one elected, the pool diminishes quite rapidly. Defeated candidates are not prone to stand for election a second time; others refuse to stand for election even one time. Some become professionally inactive or even drop out of the Society. A special committee, consisting of Stuart A. Levinson, chairman, W. C. Krumbein, and Grover E. Murray has been appointed to look into the situation and to suggest constructive action. This committee will report to the Council at its April meeting in Chicago.

Most scientific societies are affiliated with the American Association for the Advancement of Science. The American Association of Petroleum Geologists is so affiliated but our Society is not. It was deemed advisable to look into the matter of affiliation to see what privileges and responsibilities were involved. To do so a special committee consisting of Chalmer Cooper, chairman, J. Marvin Weller and H. N. Frenzel was appointed. This committee will report to the Council at its April, 1956 meeting.

W. D. Pye, our representative on the Glossary Project, asked to be relieved of his duties. His request was granted and Jules Braunstein agreed to assume the responsibilities as our representative. Assisted by R. L. Corbeille, R. H. Clark and McLain Forman, he brought our participation in the Glossary Project to a successful conclusion.

We received a request from the Society of Vertebrate Paleontologists for support of a postion taken by them respecting interpretation and administration of the "Federal Antiquities Act" an act passed by the Congress to regulate the collecting of antiquities on the public domain. The S.V.P. expressed the view that the intent of Congress was the regulation of the collection of archeological materials and that fossils were not "antiquities" as ordinarily defined. The Council considered the matter and went on record as concurring in this interpretation and supporting the appeal by the S.V.P. for an administration of the act thus construed.

Your president recommends that more positive steps be taken to better integrate the operation of the Society with that of the several sections. There is too little communication between these sections and the parent organization. To further better relations the presidents of the several sections have been invited to meet with our Council this April.

The provision that the vice-president assume full responsibility for the Annual Meetings of our Society has worked very well. We are very grateful for the efforts of our vice-president and his technical program committee for the excellence of the papers and symposia presented at Chicago this year. Special mention should also be made of the activities of the Research Committee for the organization of a symposium for these meetings and for the selection of the "best paper" awards. This committee has under consideration plans for small informal regional conferences on current research problems and progress.

Appointments made during the year include the two nominating committees, one consisting of C. C. Church, Chairman, M. N. Bramlette, and S. G. Wisslar, and the other consisting of S. A. Levinson, Chairman, H. A. Ireland, and M. A. Hanna. Other appointments include E. C. Dapples as General Chairman for S.E.P.M. and member of the Steering Committee for the 1956 joint annual meetings, J. M. Weller as Presiding Officer, for S.E.P.M. at the joint session in Chicago, Raymond Siever replacing E. C. Dapples as Chairman of the Research Committee and W. J. Plumley as a member of this committee, H. R. Wanless as S.E.P.M. delegate at the 50th centennial celebration of the Illinois State Geological Survey, Hans Thalmann as delegate to the XXth International Geological Congress at Mexico City this year, R. C. Moore as the S.E.P.M. representative on the committee for the preparation of the *Treatise on In-*

vertebrate Paleontology, and the various chairmen and co-chairmen of the technical sessions of our annual meeting, and W. M. Furnish, Chairman, C. W. Stuckey, Jr., and F. M. Swain as the Resolutions Committee for the annual meetings. W. M. Furnish was appointed Conferee to meet with the Council of the Paleontological Society at New Orleans in November, 1955.

It was moved, seconded, and carried that the above reports be approved and that they be published in the Society's publications.

The following change in the S.E.P.M. By-Laws was presented to the business meeting:

ARTICLE X. RESEARCH COMMITTEE

2. The activities of the Committee shall be directed by a chairman and a vice-chairman, to be appointed by the president, *with the approval of the council*, from the *active* members of the Committee. *The term of the appointment of the chairman shall be one year.* In the event either of these offices is vacated for any reason, the [president] *council* shall appoint a qualified replacement of the unexpired term.

The foregoing change was approved by a unanimous vote.

The meeting was turned over to incoming President Robert R. Shrock.

The Resolutions Committee, composed of W. M. Furnish, chairman, Fred M. Swain, and Charles W. Stuckey, presented the following "Resolutions of Thanks."

BE IT RESOLVED THAT in behalf of the Society we extent an expression of our sincere thanks to the following:

TO ROBERT R. SHROCK, chairman, and the members of the S.E.P.M. Technical Program Committee and to the speakers for the high quality of the papers on the 1956 program;

TO EDWARD C. DAPPLES, general chairman of the S.E.P.M. convention, for his capable handling of the details of the meeting;

TO RAYMOND SIEVER, Chairman of the Research Committee, and the members of his committee, for the excellent research symposium on Directional Properties of Sedimentary Rocks;

TO CHARLES COLLINSON, for arranging the session on Paleontology and Stratigraphy;

TO HARRY S. LADD, for preparation of the program dealing with Paleoecology;

TO LEWIS M. CLINE, for arranging the papers on Mineralogy and Sedimentary Petrology;

TO M. M. LEIGHTON, general chairman of the convention, and to the chairmen and members of all the convention subcommittees for effective leadership and organization of the Chicago meeting;

TO THE EXECUTIVE COMMITTEE of the A.A.P.G. for appropriating $1500.00 as office rent for the Society Headquarters at Tulsa;

TO ROBERT H. DOTT, for his valuable service to the Society as its Business Manager;

TO MRS. RUTH TENER, headquarters secretary, for continued interest and care of society affairs;

TO RALPH E. GRIM, who served as Acting Editor of the *Journal of Sedimentary Petrology* during the period February, 1954, to September, 1955, for his assumption of full responsibility for the *Journal* during the absence of the Editor;

TO A. K. MILLER, who served as Co-Editor of the *Journal of Paleontology* during the period January, 1955, to December, 1955;

AND TO THE CONRAD HILTON HOTEL, for providing such excellent meeting and Headquarters facilities.

It was moved, seconded, and carried that the above Resolutions be adopted.

The business session adjourned at 6:00 P.M., Tuesday, April 24, 1956.

PACIFIC SECTION

SOCIETY OF ECONOMIC PALEONTOLOGISTS AND MINERALOGISTS

Nov. 10 and 11, 1955, Biltmore Hotel, Los Angeles, Calif.

Thursday Evening

S.E.P.M. ANNUAL DINNER AND EVENING SESSION

Presiding: HAROLD G. BILLMAN, President, Pacific Section, Society of Economic Paleontologists and Mineralogists, Union Oil Company of California, Bakerfield; AND E. H. STINEMEYER, Secretary-Treasurer, Pacific Section, Society of Economic Paleontologists and Mineralogists, Shell Oil Company, Bakersfield

FORAMINIFERAL ZONATIONS IN THE TERTIARY SEQUENCE OF SOUTHWESTERN WASHINGTON

WELDON W. RAU

U. S. Geological Survey, Menlo Park

Detailed stratigraphic and foraminiferal studies of the Tertiary rocks of southwesrtern Washington are being made by the U. S. Geological Survey to provide more precise correlation and dating of these coal-bearing and potential oil-bearing strata. Foraminiferal zonations based on these studies have been established for a thick but poorly exposed sequence of rocks that is characterized in part by rapid lateral and vertical changes in lithofacies and in part by similar lithologies in rocks of different ages. In places correlations are hampered by intercalated volcanic flows.

Thirteen measured surface and subsurface sections that are believed to be representative of the Tertiary rocks in southwestern Washington have been used as the basic framework for dividing these rocks of Eocene, Oligocene, and Miocene (?) age into eight foraminiferal zones. Faunal characteristics of each zone are discussed and stratigraphic limits assigned on the basis of highest and lowest occurrences of species. The assemblages are compared with known faunas of the Pacific Coast and particular consideration is given to those referred to Laiming's Eocene zones of California and Kleinpell's Oligocene and Miocene stages of California. Faunal similarities suggest regional correlations and age determinations ranging from possibly as low as Laiming's Eocene B-2 zone of California to Kleinpell's "Oligo-Miocene" Saucesian stage of California.

Friday Morning

Presiding: E. H. STINEMEYER, Shell Oil Company, Bakersfield

1. FORAMINIFERA OF SANTA CRUZ BASIN

JOHANNA RESIG

University Southern California

Santa Cruz Basin is one of the many basins composing the unique offshore area known as California's "Continental Borderland." The basin is located to the south of Santa Cruz Island and reaches a depth of over 6400 feet. A difference in depth of 2900 feet between the sill and the basin bottom provides for a large area of relatively uniform conditions below the sill. Santa Cruz Basin, therefore, serves as an ideal location for the study of the effects of a basin environment upon foraminiferal distribution.

From a series of bottom samples taken at depths ranging from 450 to 6120 feet within the basin, a study of the living and dead foraminifera was made. At the sill, *Bolivina minuta, Cassidulina cushmani, Cassidulina delicata, Epistominella* sp., and *Virgulina nodosa* were found living, with all but the latter well represented in the dead population. In another sample taken near sill level but at the side of the basin, additional living species were *Volivina spissa, Epistominella smithi, Globobulimina pacifica, Pullenia salisbury, Uvigerinaiperegrina, Valvulineria inaequalis,* and *Virgulina seminuda.*

Comparing the assemblage at or above sill level with the foraminifera living in the basin depths, it was found that only one species was living near the bottom which was not also living near the sill. In three samples taken well below sill level, *Chilostomella ovoidea, Epistominella* sp., *Epistominella smithi, Fissurina marginata* var., *Globobulimina pacifica,* and *Uvigerina peregrina* were found living. While *Chilostomella ovoidea* was restricted to the deeper waters, and *Fissurina marginata* var., and *Globobulimina pacifica* to depths from just above the sill to the bottom, their tests are not correspondingly abundant among the dead populations. This could be attributed to a number of factors including slower reproductive habits of the species, or migration. Forms abundant in the dead population which were not found to be living are *Bolivina minuta* and *Cassidulina delicata.* It is possible that displacement down slope has occurred as the species were found living at a higher level.

Trends which were noted in vertical distribution include: (1) a decrease in the number of genera and species with depth, with a pronounced reduction below sill level; (2) a decrease in the number of living individuals in 100 grams of sediment with depth (at sill level and below there are three to sixteen, and above sill level five to 275 individuals per 100 grams); (3) a general decrease in the percent of planktonic tests with depth (above sill level, the average

plankton content is 54%, while below this level, it is 23%).

2. A RESTUDY OF THE MOHNIAN-DELMONTIAN CONTACT NEAR CALABASAS, CALIFORNIA

F. W. BERGEN, JR.
Shell Oil Company, Bakersfield

The type localities of the *Bolivina hughesi* zone of the upper Mohnian and the *Bolivina obliqua* zone of the lower Delmontian, as defined by R. M. Kleinpell, are on the north flank of the Santa Monica Mountains along Topanga Canyon Road. Because of a scarcity of foraminifera between the good *Bolivina hughesi* faunas and the good *Bolivina obliqua* faunas, the contact between the two zones was based on a lithologic change within the barren zone.

Subsequent sampling in the vicinity of the type sections by M. L. Bramlette produced scattered foraminifera, among which were species found in neither the *Bolivina hughesi* nor *Bolivina obliqua* faunas. There was a suggestion of a new zone comprising the "barren" sequence between Kleinpell's zones.

A restudy of the entire sequence of zones, three miles to the west near Calabasas, was begun in 1951. In the Calabasas area, between the highest *Bolivina hughesi* fauna and the lowest *Bolivina obliqua* fauna, are 730 feet of shale with numerous thin beds of limestone. The shale outcrops of this interval are barren, as they are in the type section, but the limestone beds contain a very distinctive fauna. Some of the species characteristic of the fauna are: *Cassidulinoides californiensis, Pulvinulinella purisima, Virgulina californiensis* var. *grandis*, and *Virgulinella pertusa*. The conclusion drawn is that the relatively barren beds heretofore assigned to the top of the *Bolivina hughesi* zone and the lower part of the *Bolivina obliqua* zone should be given zonal status intermediate to those zones. For the present, the interval is given the name Intermediate zone.

3. UPPER AND MIDDLE MIOCENE FORAMINIFERA FROM SOUTHEASTERN PART OF THE LOS ANGELES BASIN, CALIFORNIA

PATSY SMITH
U. S. Geological Survey, Pomona College, Claremont

In the southeastern part of the Los Angeles Basin (Santa Ana Mountains, San Juan Capistrano area, and San Joaquin Hills) thick sections of upper and middle Miocene sedimentary rocks are exposed. Foraminifera have been collected and studied from five geographic units: the northern and central Santa Ana Mountains, the southwestern Santa Ana Mountains, the east flank of the Capistrano syncline, the west flank of the Capistrano syncline, and the Newport Lagoon area. The faunal assemblages of each area are compared with the California Miocene stages proposed by Kelinpell in 1934.

The upper part of the Topanga formation contains faunas of middle Miocene (Relizian ? stage) age. The Topanga formation is overlain by rocks varying in age from middle Miocene (Luisian stage) to upper Miocene (Mohnian stage).

In the northern and central Santa Ana Mountains, the Topanga formation is overlain by the Puente formation of upper Miocene age.

In the southwestern Santa Ana Mountains, north of the town of El Toro, the Topanga formation is overlain by a thin section of the Puente formation. Faunal correlations within the Puente formation in this area are very poor, shallow-water forms predominating.

In the Capistrano syncline, south of the El Toro air station, the Topanga is overlain by the Monterey shale, On the east flank of the syncline the Monterey shale consists of about 100 feet of rocks of the upper part of the Luisian stage and about 1200 feet of rocks of the Mohnian stage.

On the west flank of the syncline, the Monterey shale consists of about 20 feet of rocks assigned to the lower part of the Luisian stage, about 320 feet of rocks assigned to the upper part of the Luisian stage, and 0 to 200 feet of rocks of the Mohnian stage.

At Newport Lagoon the Topanga is overlain by rocks of the Monterey shale assigned to the Luisian and Mohnian stages.

Changes of thickness of rocks assigned to Kleinpell's Luisian and Mohnian stages are due to uncomformities and local depositional variations. No evidence was found to indicate that foraminiferal faunas assigned to the Mohnian stage grade laterally into faunas of the Luisian stage.

4. EOCENE DIATOM FLORULES OF THE KELLOGG AND SIDNEY SHALES, MT. DIABLO AREA, CALIFORNIA

TARO KANAYA
Scripps Institution of Oceanography, La Jolla

This paper describes diatom species of Eocene shales from two different horizons, the Kellogg and Sidney shales, in Mt. Diablo area, and establishes a local standard diatom sequence of the "Kreyenhagen shale" in California.

The shales occur in the area north and northeast of Mt. Diablo, middle California; the Sidney shale is a middle member of the Markley formation, and the Kellogg shale is believed to lie below the Markely formation. Eighteen samples, nine from the Kellogg and nine from the Sidney, all collected in the same sections from which Clark and Campbell described the radiolarian faunas, are selected for the present study to represent 85 feet of the Kellogg shale and 90 feet of the highly diatomaceous part of the Sidney shale.

Thirty-nine species, including one new, are described from the samples, and the relative abundances of the species are summarized in a chart which shows the diatom assemblages of both shales in sequence. On the basis of this distribution, and their previous records of occurrences mainly in California, seventeen species, all common to the Kellogg and Sidney shales, characterized positively the Eocene Mt. Diablo florules here discussed from those of the Cre-

taceous and Miocene, previously reported from California localities.

The chart is analyzed from statistical aspects, and it is found that, by using the characteristic seventeen species, the samples of the two different stratigraphic units, the Kellogg and Sidney shales, can be distinguished objectively, in terms of the relative abundances and joint occurrences of the species.

5. LOWER CRETACEOUS STRATIGRAPHIC UNITS OF NORTHERN CALIFORNIA

MICHAEL A. MURPHY

University of California, Riverside

A thick succession of fossiliferous Lower Cretaceous clastic rocks crops out near Ono, California. Although these rocks have been studied by California geologists and paleontologists for almost 100 years, no detailed maps or sections have ever been published.

This district is the type area for the stratal unit previously called the Horsetown "group" or "formation," here redefined as the Horsetown stage. Eight biostratigraphic zones, ranging in age from Hauterivian to late Albian in the European time scale are defined within this stage. The upper and lower boundaries of the stage are defined by the bases of the zones of *Pervinquieria hulenana* and of *Neocraspedites aguila* respectively.

Two new formations are recognized within the mapped area; the Rector formation, a thin sandstone and conglomerate unit, is markedly transgressive and lies upon the igneous and metamorphic rocks of the Klamath Mountains; the Ono formation, a thick mudstone unit with two coarse clastic tongues, lies on the Rector formation and underlies unnamed conglomerate units of probable late Albian age. The rocks of the Ono formation are predominantly mudstone with nodular limestone; graywacke and conglomerate comprise about 30 per cent of the section. The boundaries of the lithologic units are not coincident with those of the Horsetown stage.

A southeast-dipping homocline complicated by numerous small and several larger transcurrent faults is the main structural feature of this area.

6. SOME FORAMINIFERA FROM ROCKS OF EOCENE AGE ON SAN NICOLAS ISLAND, VENTURA COUNTY, CALIFORNIA

MERLE C. ISRAELSKY

U. S. Geological Survey, Menlo Park

San Nicolas Island is the most seaward of the Channel Islands which lie off the coast of southern California. It consists of Eocene sandstones and siltstones that form a complexity faulted anticline. Except along the sea cliffs the Eocene strata are generally mantled by marine deposits of Pleistocene age, sand dunes, and Indian kitchen mounds.

Faunal collections from a number of measured sections are used in an attempt to establish correlations and zone the outcropping Eocene. The Eocene rocks appear to be equivalent in age to the Kreyenhagen of the San Joaquin Valley.

ANNOUNCEMENT

S.E.P.M. PROGRAM FOR ST. LOUIS MEETING

APRIL 1–4, 1957

The Society of Economic Paleontologists and Mineralogists is planning a program for the St. Louis 1957 meeting which will consist of the following:

1. A joint session with the A.A.P.G.

2. A session of volunteered papers on paleontology and stratigraphy, with Shepard W. Lowman, Rensselaer Polytechnic Institute, Troy, New York, as Chairman.

3. A session of volunteered papers on sedimentary mineralogy and petrology and sedimentology, with Sherman A. Wengerd, University of New Mexico, Albuquerque, as Chairman.

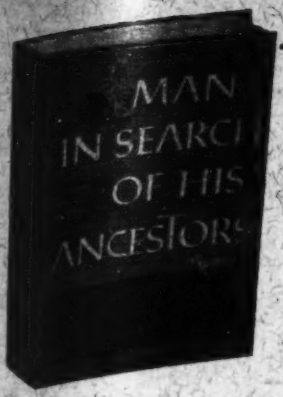
4. A symposium on "Biostratigraphy," with emphasis on the role of evolution in stratigraphic paleontology, to be organized by the Research Committee, with Curt Teichert, U. S. Geological Survey, Federal Center, Denver, Colorado, as Chairman.

5. A symposium on "Geochemistry of Sedimentary Materials" is tentatively planned, with William J. Plumley, California Research Corporation, La Habra Laboratories, La Habra, California, and Heinz A. Lowenstam, California Institute of Technology, Pasadena, as Co-Chairmen.

All persons interested in submitting papers for this program or who have suggestions for the symposia should write directly to the Chairman of the particular session.

November 1 is the deadline for the submission of abstracts and papers for any part of the program. We earnestly solicit your cooperation and aid in order that we may organize and carry through what we hope may be one of our outstanding programs.

R. V. HOLLINGSWORTH
Chairman, Technical Program



An important NEW book
for every paleontologist!

MAN IN SEARCH OF HIS ANCESTORS

by Andre Senet

Illustrated with 110 drawings and 12 pages photographs

The origin of man—the exciting hunt that man has pursued through the ages in search of his ancestors—is the subject of this vivid and dramatic history of paleontology. Part of the brilliant Plon series which has included such best sellers as GODS, GRAVES AND SCHOLARS; ANIMALS, MEN, AND MYTHS: and CONQUEST BY MAN, the book is at once scholarly, dramatic, and highly interesting.

Ingeniously, Monsieur Senet takes the reader back through paleontological history to the dawn of time. Along the way he comments on the exciting clues and discoveries paleontology has uncovered which throw light on the field, outlines the main stages of evolution, and speculates on the "superman" of the future.

at all bookstores $5.50 **McGRAW-HILL**

YOU CAN GET A WEALTH OF ACCURATE INFORMATION with the SCHLUMBERGER CONTINUOUS DIPMETER

A THREE-IN-ONE SERVICE
Combining
THE DIPMETER,
THE DIRECTIONAL
AND THE MICRO-CALIPER SURVEYS

This improved Schlumberger three-in-one Dipmeter will do more than any similar service to help solve your structural, stratigraphic and production problems. It gives you these never-before-available money saving advantages:

A Directional Survey and a Micro-Caliper run simultaneously with the Dipmeter at no extra cost. All are necessary for accurate dip resolution, but they also give you additional information valuable in the completion of your well.

Sharp formation detail is obtained by using MicroLog curves for bed correlation. This increases the accuracy of dip calculations, particularly on low angle dips.

The continuous record makes it possible to accurately locate fault zones.

All measurements are recorded at the surface, thus eliminating the down-hole directional film.

It operates with high efficiency in shallow or deep, high temperature wells.

It saves many hours of valuable rig time by giving you three operations in one continuous run.

You can be sure of your Dipmeter Survey if it is run by Schlumberger.

THE EYES OF THE OIL INDUSTRY **SCHLUMBERGER**
Well Surveying Corporation